Multiple Access Control
WiFi introduction

Multiple Access Control Channels

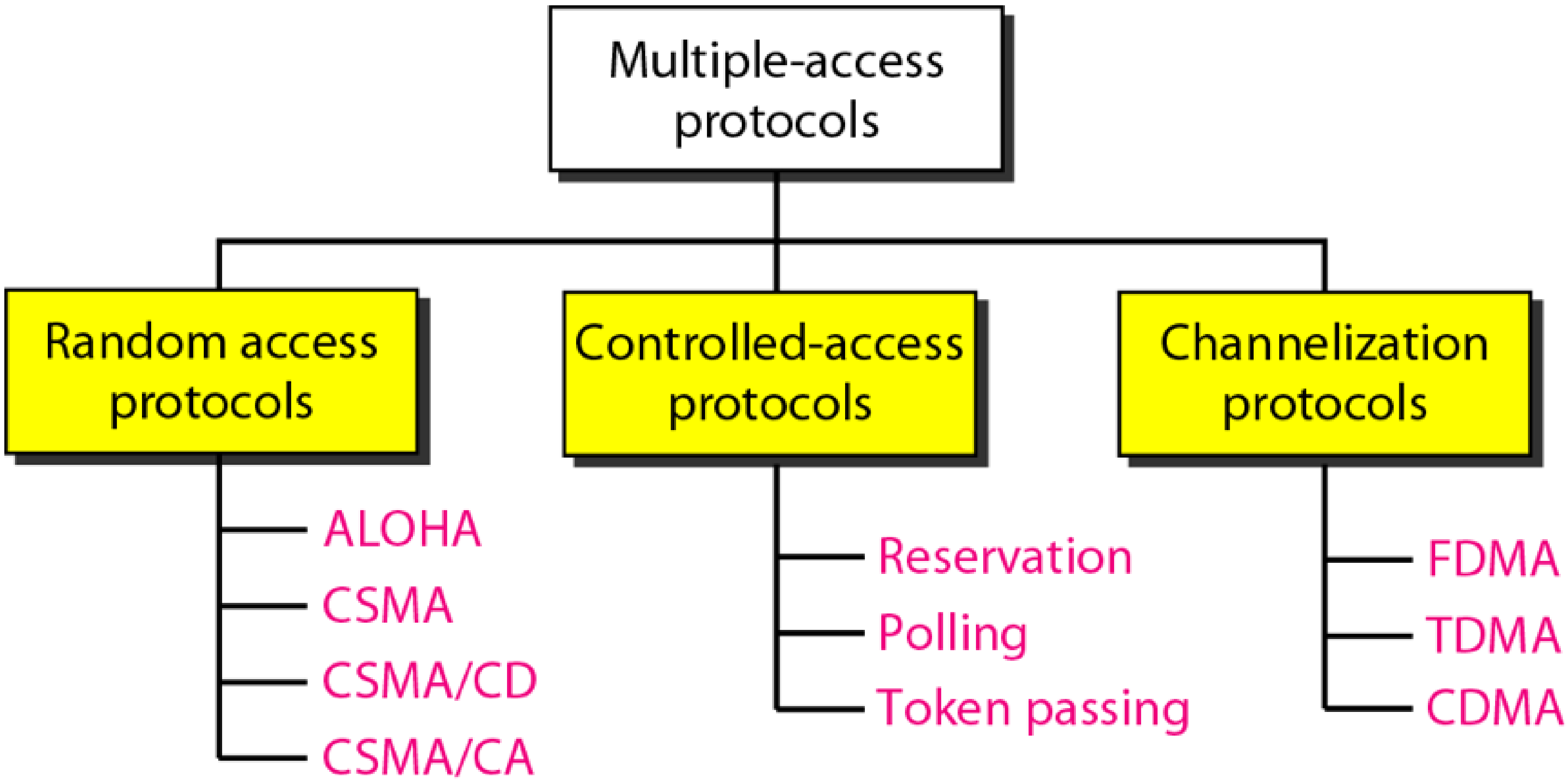
- N independent stations
  - Assumption of limited or unlimited number
  - Poisson arrivals
  - Fixed packet length
- Single Channel
- Collisions are possible
  - Carrier sensing
  - Collision detection
- Time assumptions
  - Segmented non-continuous time / Synchronous mode
  - Non-segmented continuous time / Asynchronous mode

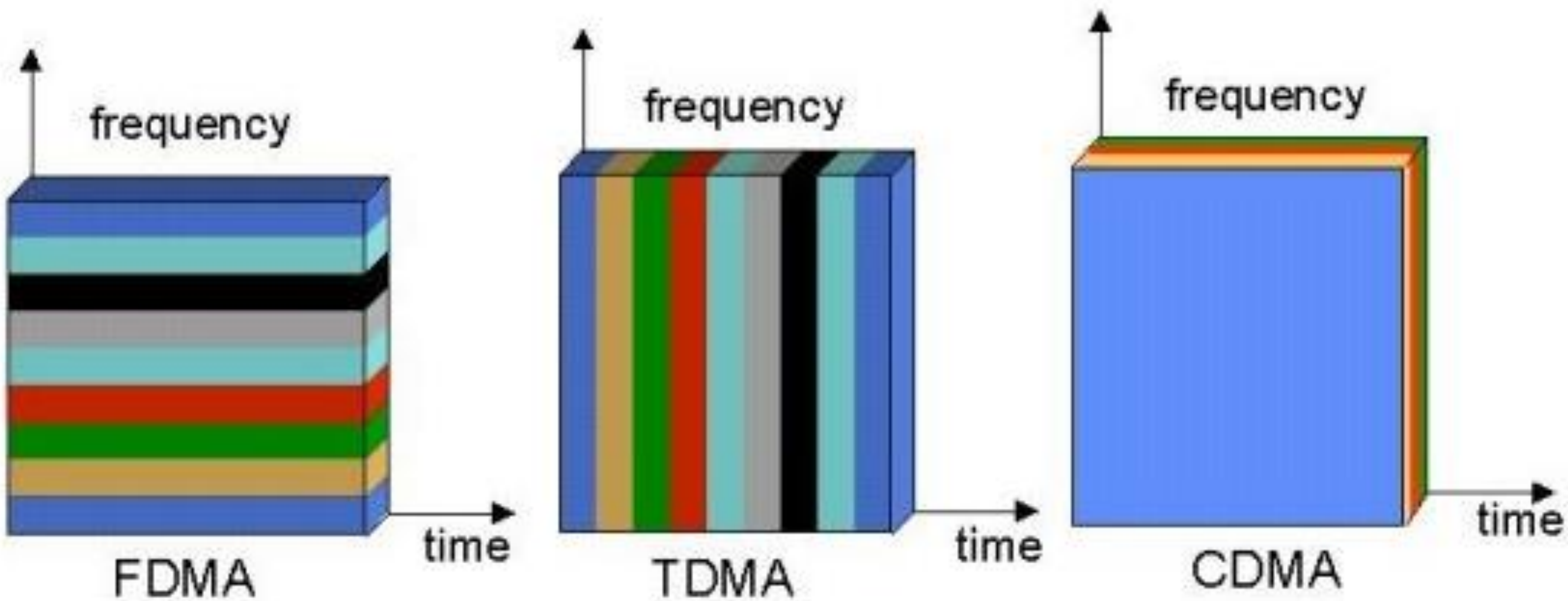
Multiplexing Techniques

- Multiplexing techniques are used to allow many users to share a common transmission resource. In our case the users are mobile and the transmission resource is the radio spectrum. Sharing a common resource requires an access mechanism that will control the multiplexing mechanism.
- As in wireline systems, it is desirable to allow the simultaneous transmission of information between two users engaged in a connection. This is called duplexing.
- Two types of duplexing exist:
  - Frequency division duplexing (FDD), whereby two frequency channels are assigned to a connection, one channel for each direction of transmission.
  - Time division duplexing (TDD), whereby two time slots (closely placed in time for duplex effect) are assigned to a connection, one slot for each direction of transmission.

Multiplexing

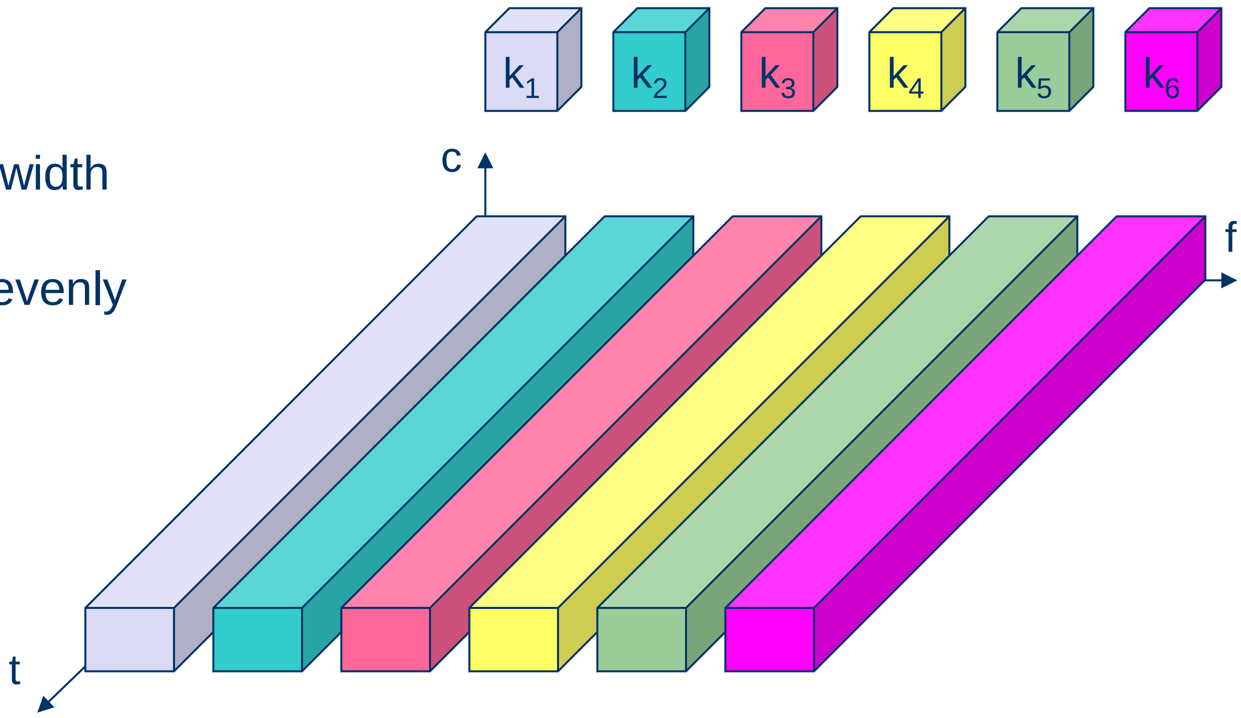
- Multiplexing allows parallel transmission from different sources, handling interference.
- Three basic kinds
  - **TDM/TDMA** (Time Division Multiple Access)
  - **FDM/FDMA** (Frequency Division Multiple Access)
  - **CDMA** (Code Division Multiple Access)
  - Combinations of the above


Multiple-access protocols
Random access protocols
Controlled-access protocols
Channelization protocols
ALOHA
CSMA
CSMA/CD
CSMA/CA
Reservation
Polling
Token passing
FDMA
TDMA
CDMA


frequency
time
FDMA
frequency
time
TDMA
frequency
time
CDMA

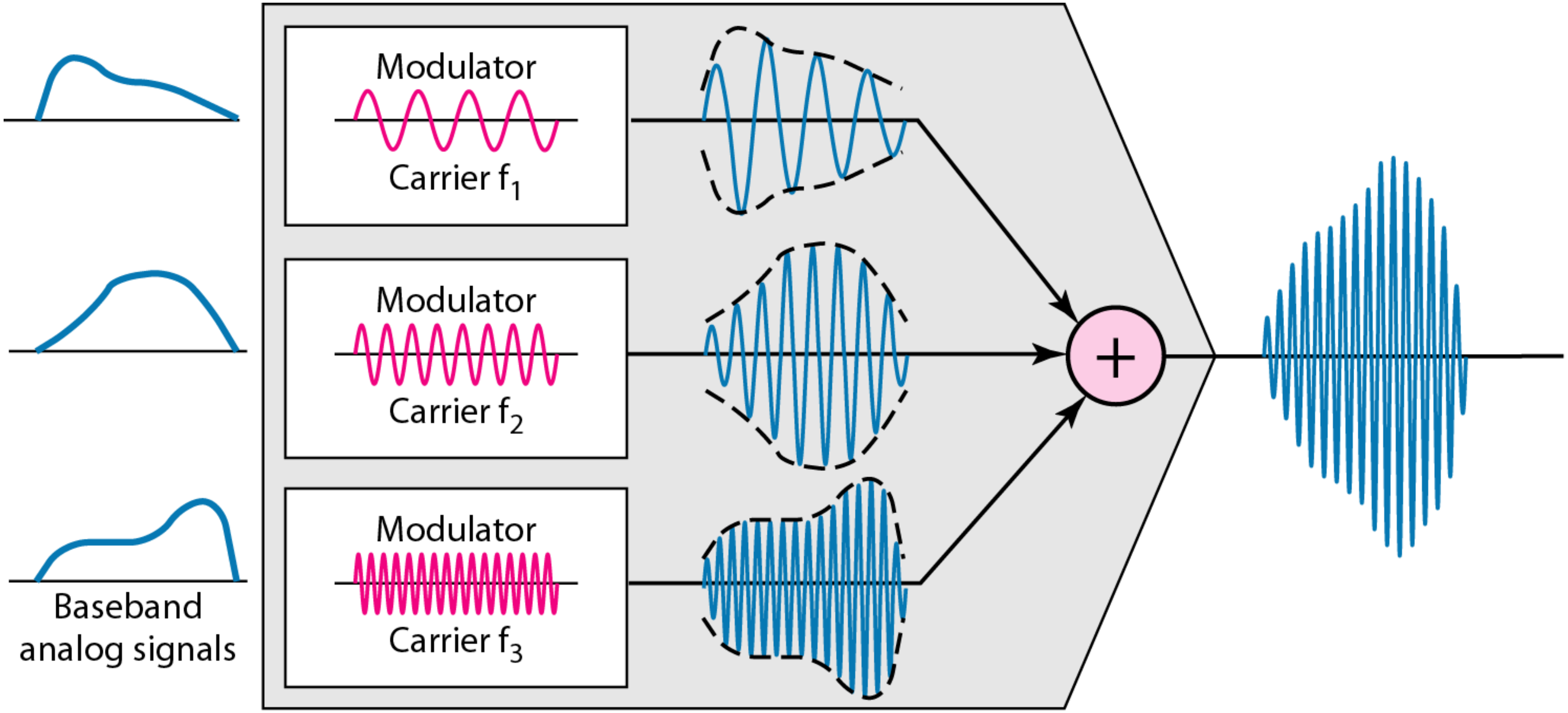
Frequency Division Multiplexing (FDM)

- Separation of the whole spectrum into smaller frequency bands
- A channel gets a certain band of the spectrum for the whole time
  Advantages:
  - no dynamic coordination necessary
  - works also for analog signals
  - cheaper
- Disadvantages:
  - waste of bandwidth if the traffic is distributed unevenly
  - inflexible

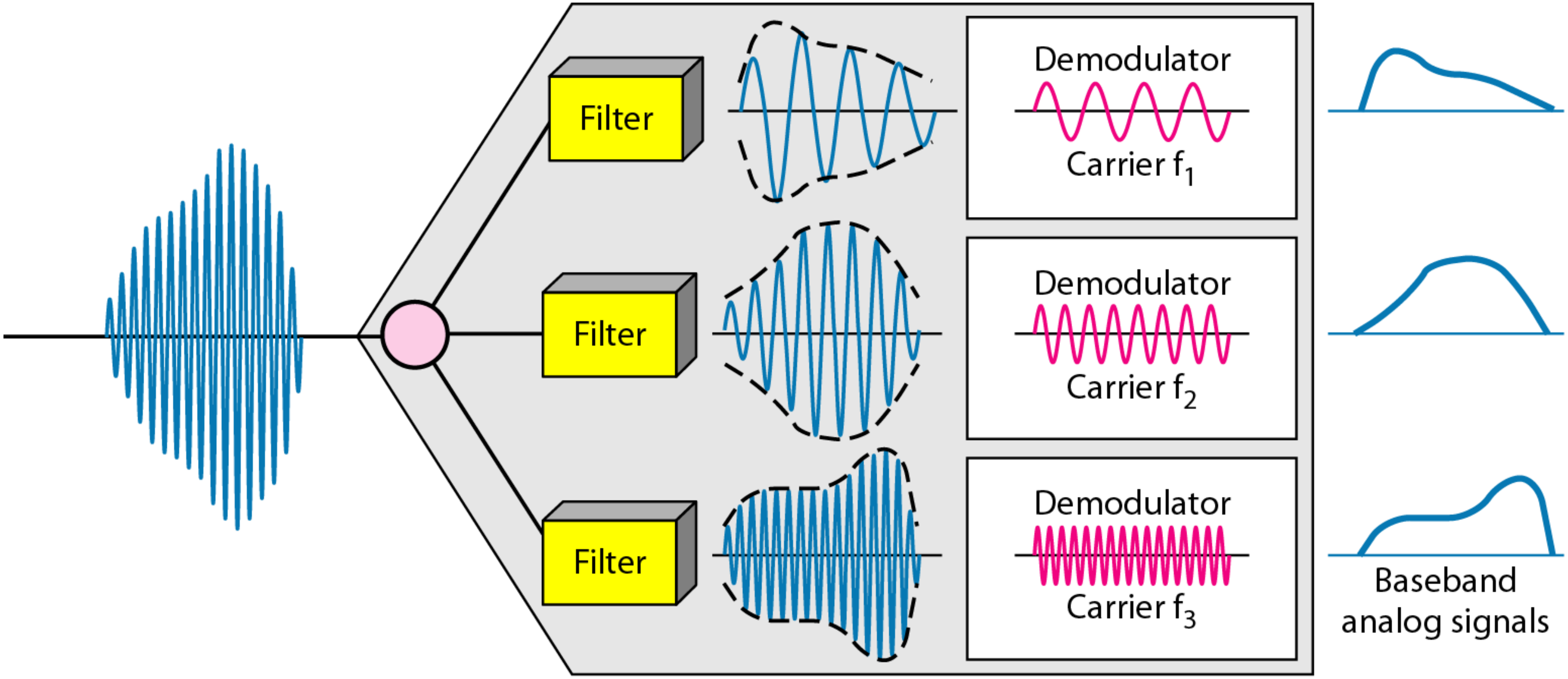


Frequency Division Multiplexing (FDM)

Frequency Division Multiplexing (FDM)

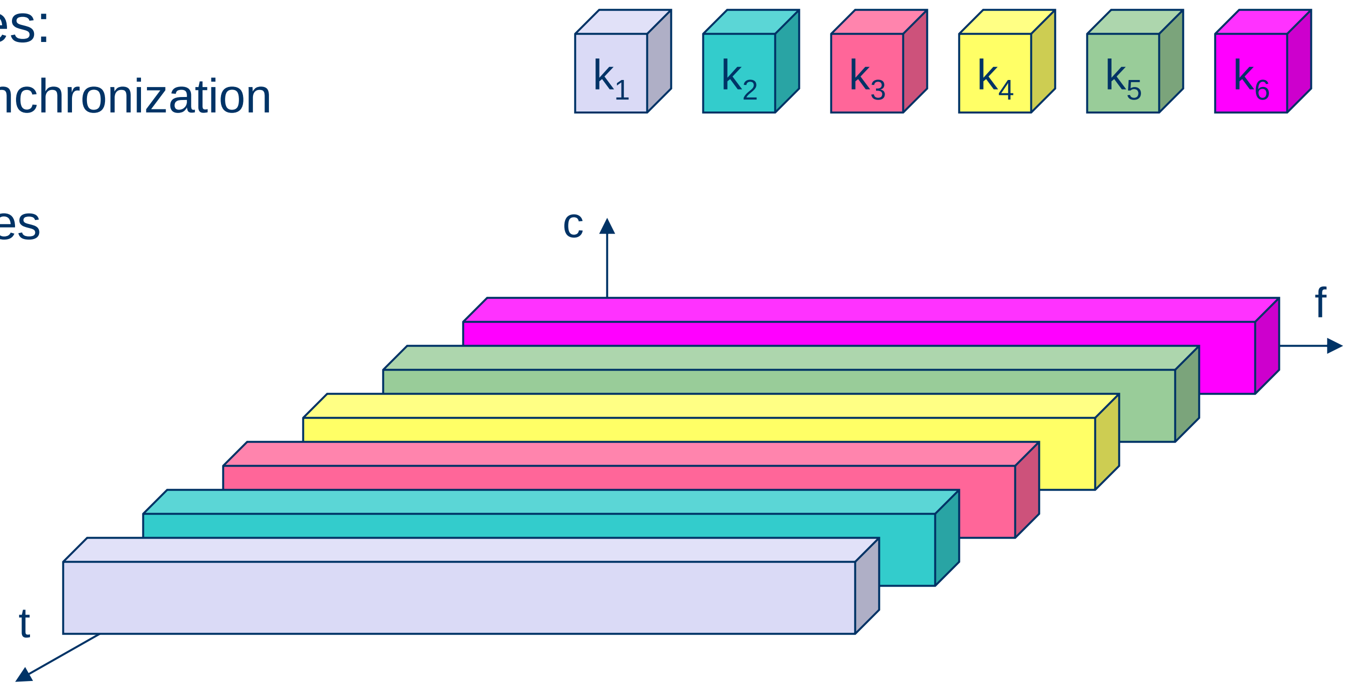


Frequency Division Multiplexing (FDM)

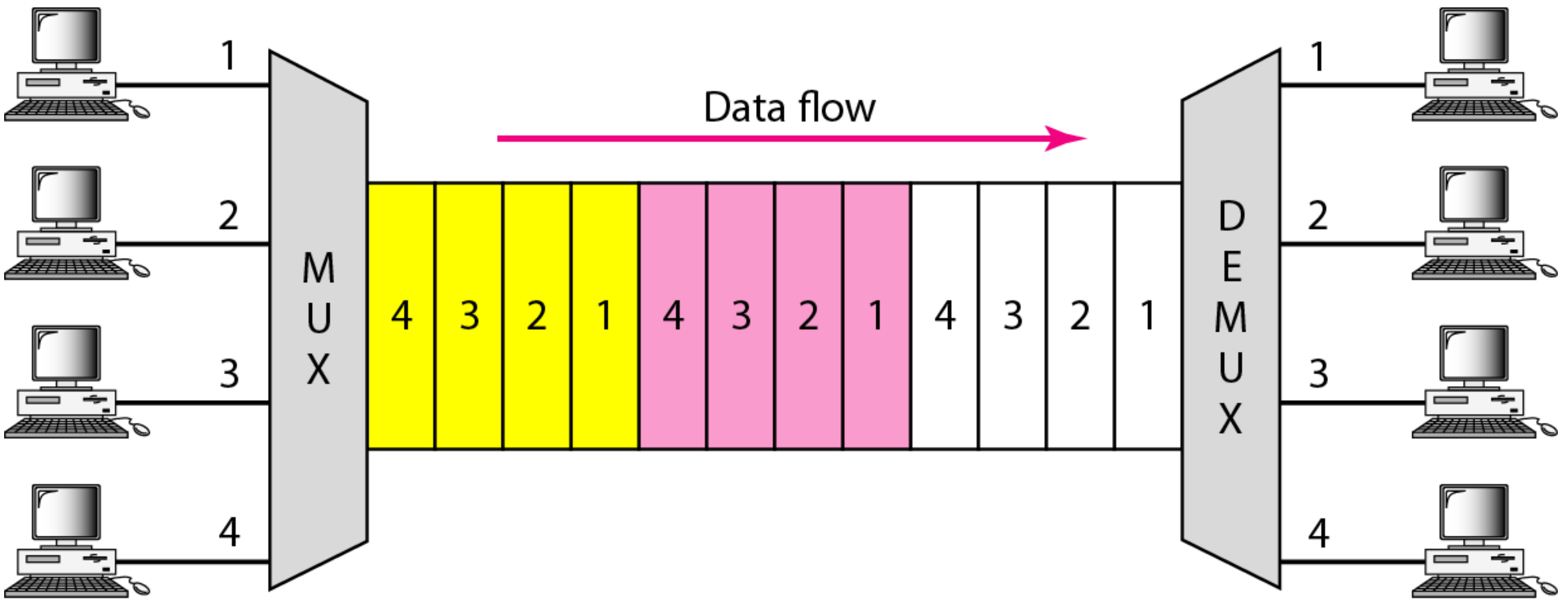


Time Division Multiplexing (TDM)

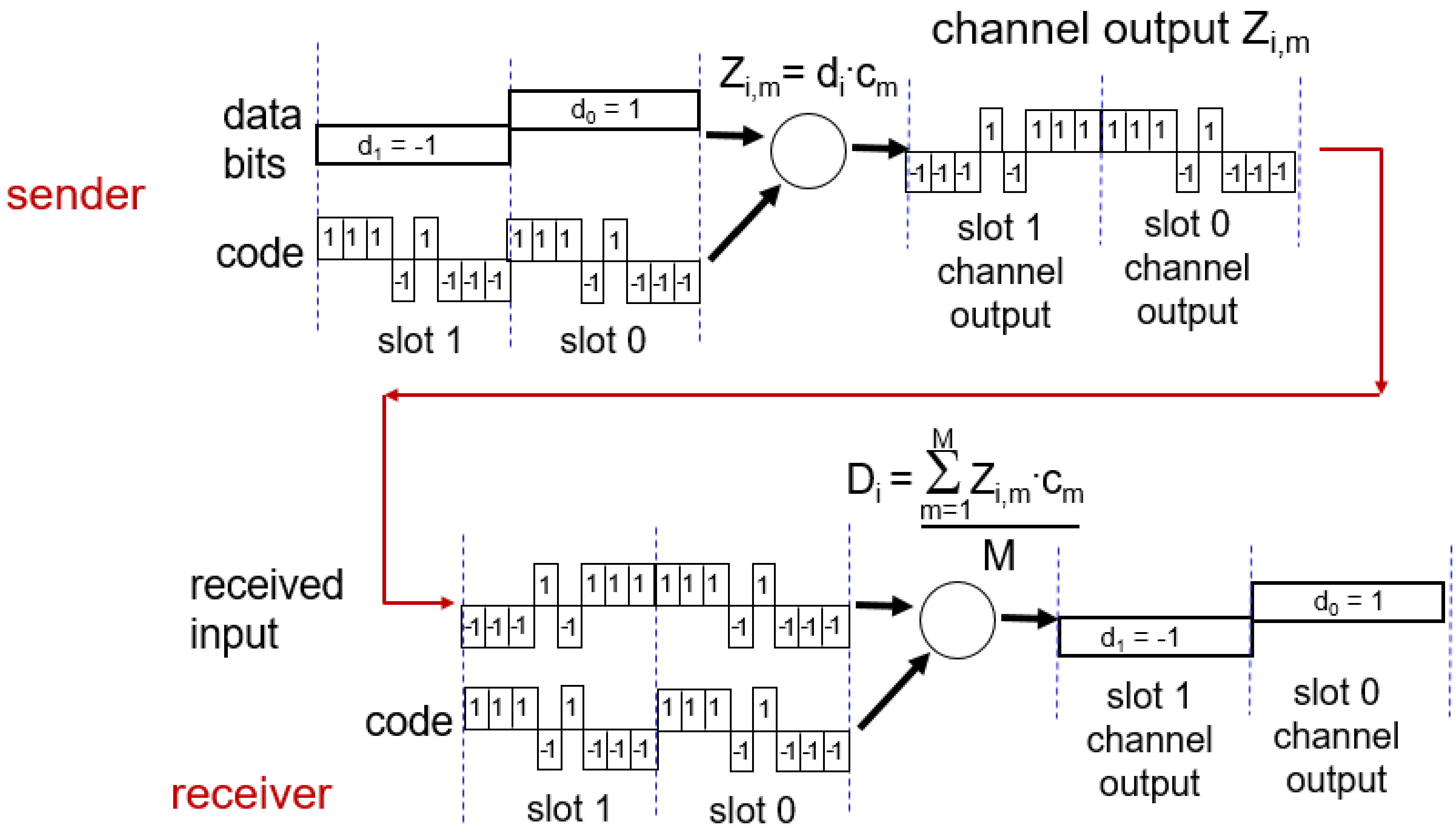
- A channel gets the whole spectrum for a certain amount of time
- Advantages:
  - only one carrier in the medium at any time
  - throughput high - supports bursts
  - flexible – multiple slots
- Disadvantages:
  - Precise synchronization necessary
  - high bit rates at each Tx/Rx



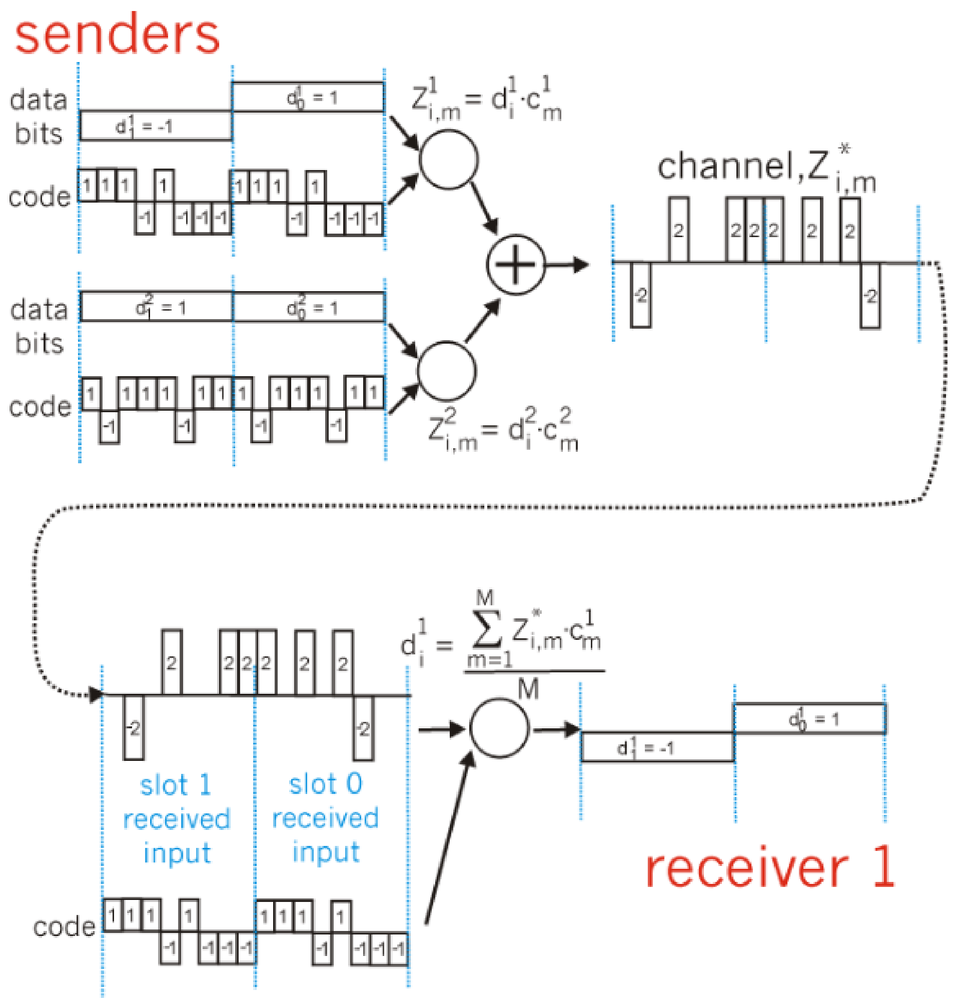
Time Division Multiplexing (TDM)



Code Division Multiple Access (CDMA)



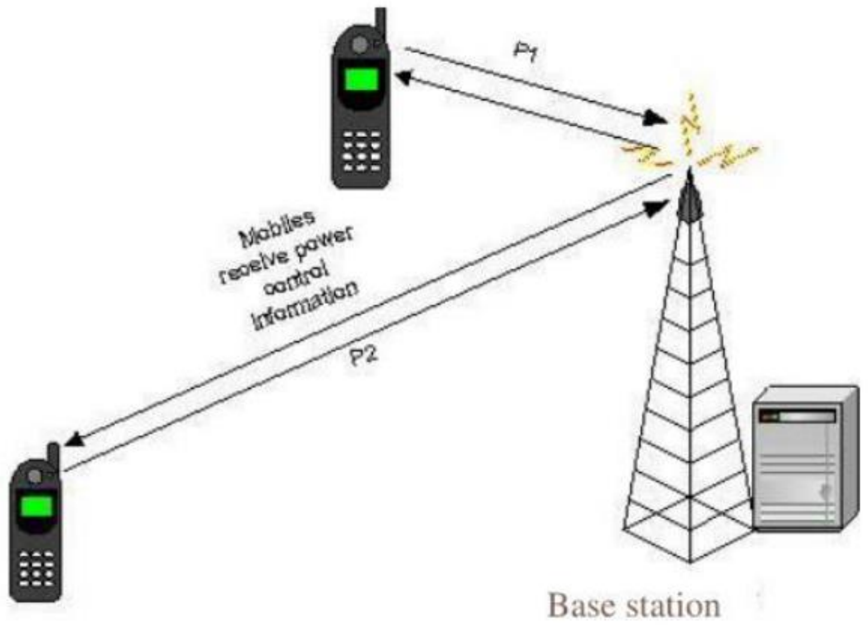
Code Division Multiple Access (CDMA)



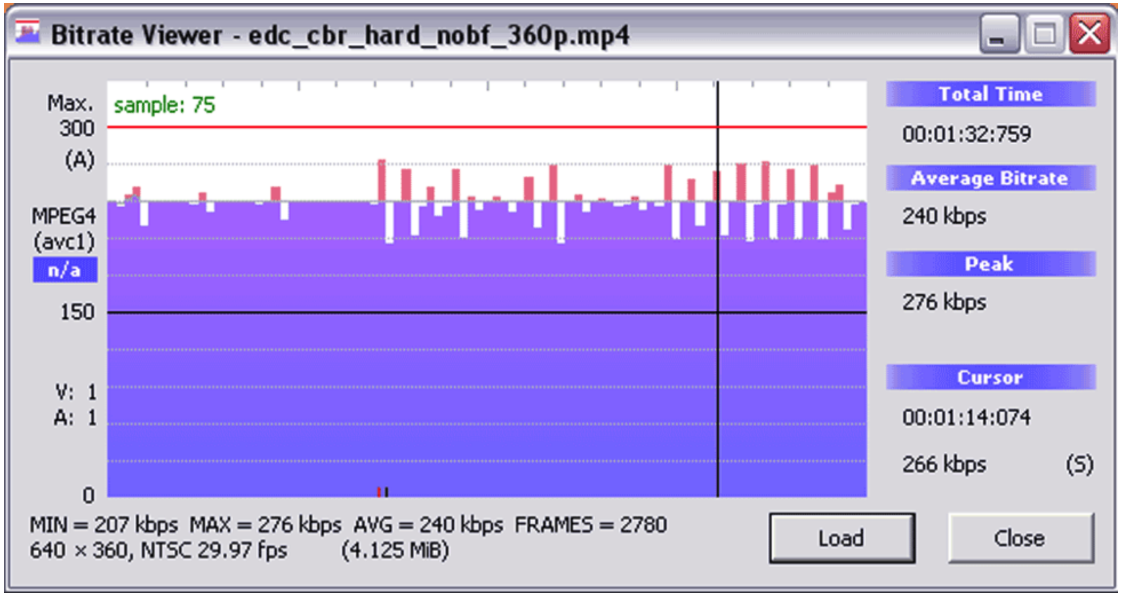
Near-far problem in CDMA

- A CDMA receiver cannot successfully de-spread the desired signal in a high multiple-access-interference environment
- Unless a transmitter close to the receiver transmits at power lower than a transmitter farther away, the far transmitter cannot be heard
- Power control must be used to mitigate the near-far problem
- Mobiles transmit at such power levels to ensure that received power levels are equal at base station

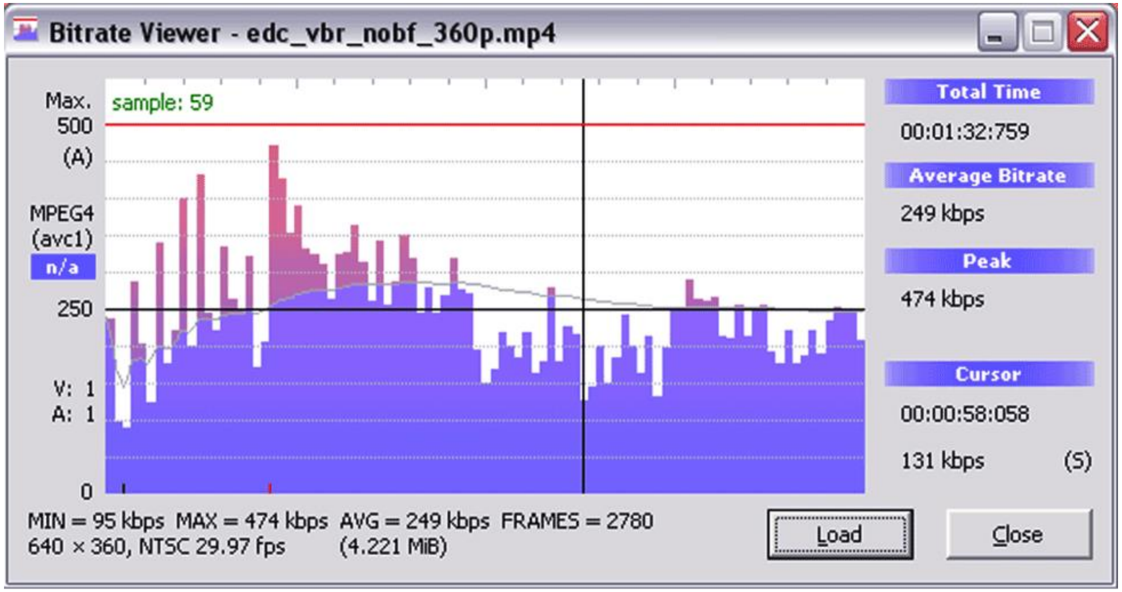
- Power control and channel problems!



Constant / Variable Bit Rate



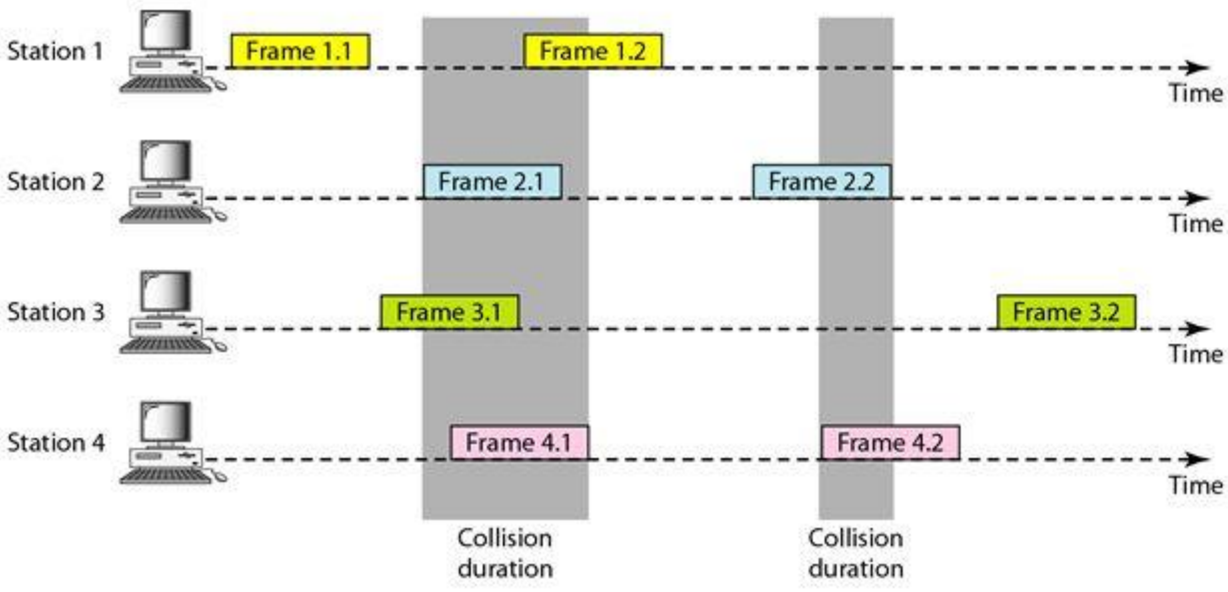
CBR



VBR

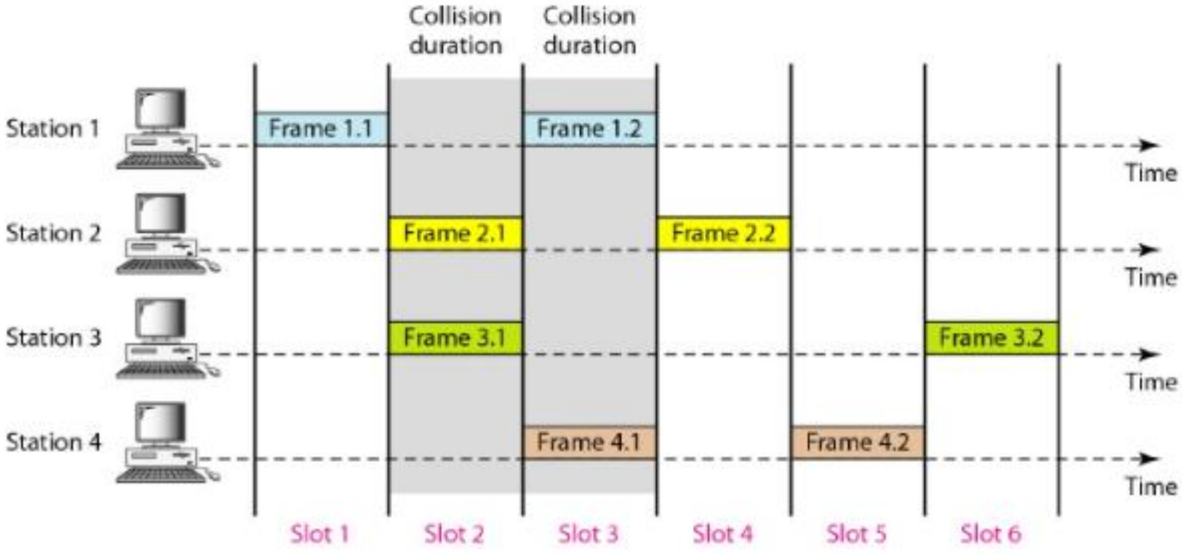
Pure ALOHA

- Continuous time, transmission at any moment.
- No synchronization, packet transmission upon arrival at the queue.
- On collision, the packet is retransmitted after random time.

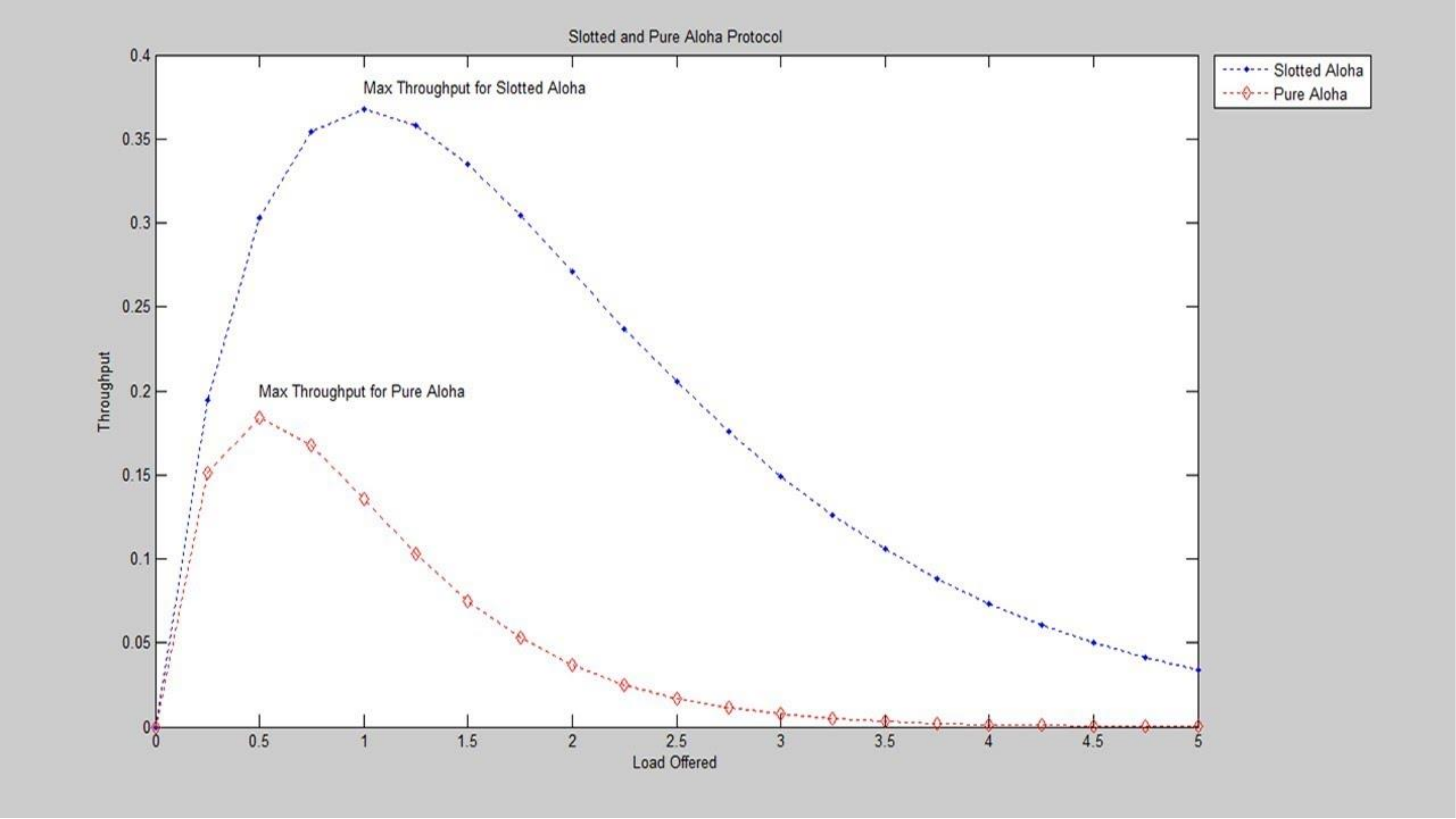


Slotted ALOHA

- Fixed packet length
- Timeslot=packet transmission time
- Each packet is transmitted at the first timeslot after arrival
- Synchronization is required
- On collision, the packet is retransmitted after random timeslots



Throughput



Slotted and Pure Aloha Protocol
Max Throughput for Slotted Aloha
Max Throughput for Pure Aloha
Slotted Aloha
Pure Aloha
Throughput
Load Offered
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

ALOHA performance

- Unstable behavior: one packet can have low or high delay for the same throughput
- Low throughput = 18% ή 36%
- But
  - Very simple to implement
  - Low delay for low traffic
  - Delay independent to the total number of nodes

Carrier Sense Multiple Access(CSMA)

- One node can listen if other nodes transmit (this a small delay depending on distance
- Transmission can be postponed, if a collision is going to happen
- Not all collisions are avoided due to delay in signal propagation

CSMA PROTOCOLS

Non-persistent CSMA

- Packets arriving in empty slots are transmitted instantaneously
- If the slot is busy, the transmission is rescheduled after random time (virtual collision)
- Good throughput
- Good distribution of traffic in time
- Delay is increasing for higher traffic

CSMA PROTOCOLS

1-persistent CSMA

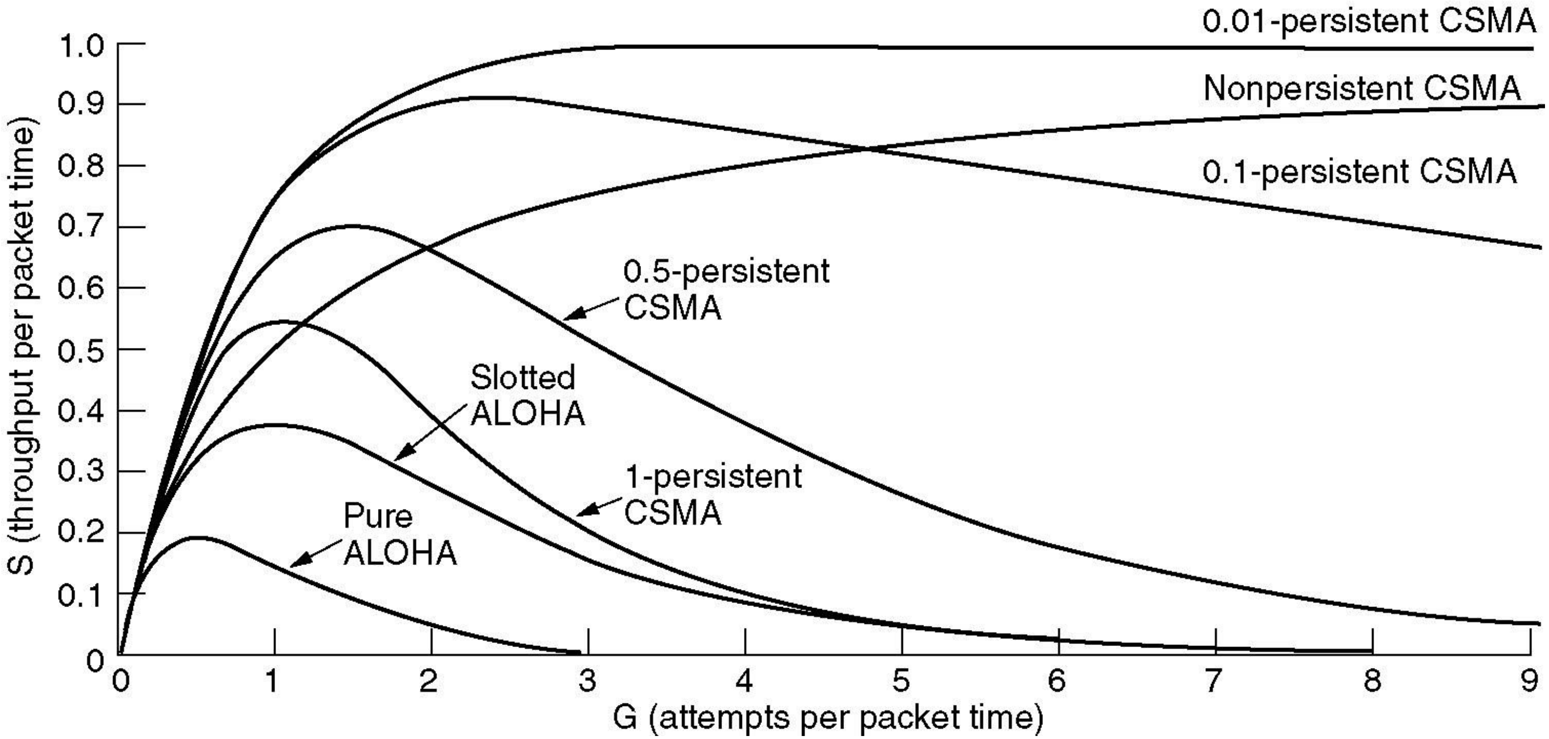
- Packets arriving in empty slots are transmitted instantaneously
- If the slot is busy, wait until the next empty slot and transmit
- Low delay in low traffic
- Max throughput not that impressive
- At the end of an existing transmission, collision probability if high

CSMA PROTOCOLS

P-persistent CSMA

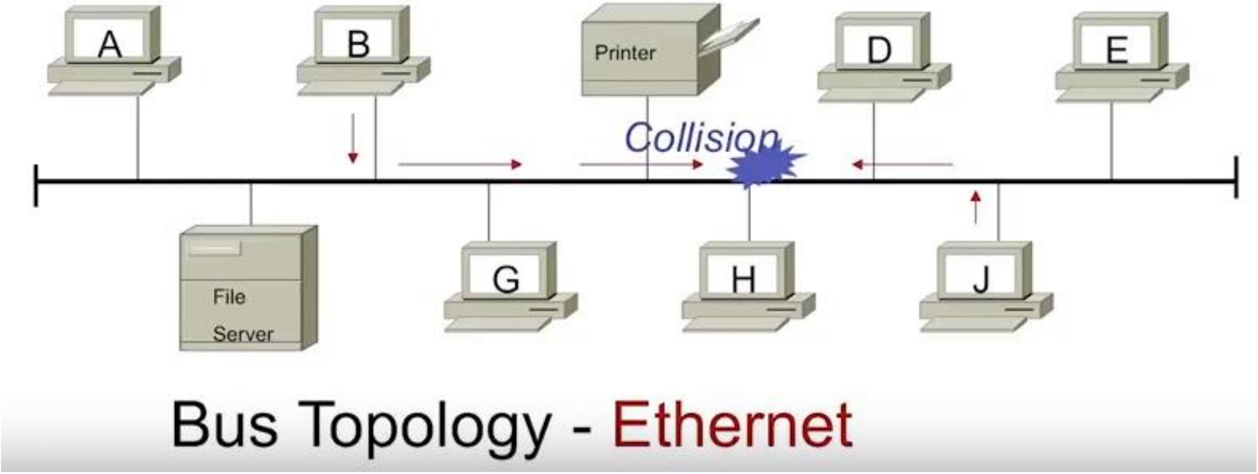
- Packets arriving in empty slots are transmitted instantaneously
- If the slot is busy, wait until the next empty slot and transmit with probability P
- With probability 1-P repeat the procedure in the next slot

A comparison of simple protocols

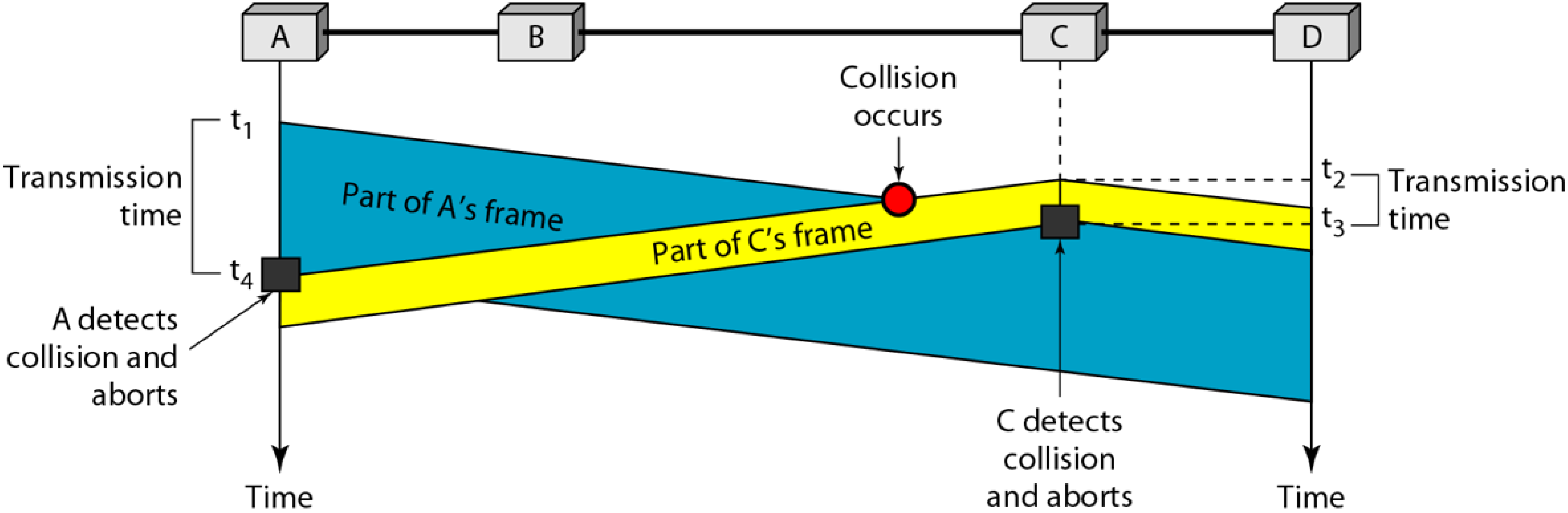


Carrier Sense Multiple Access Collision Detection (CSMA/CD)

- each node can listen to the medium **before transmission, while the channel allows listening while transmitting**
- On collision detection:
    - quits transmission
    - waits a random time period and retries
- **hard to implement in wireless communications**
- Used in Ethernet

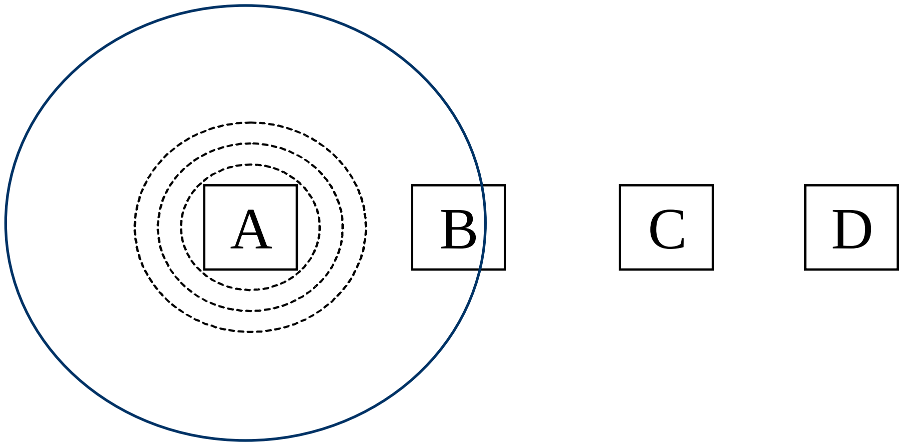


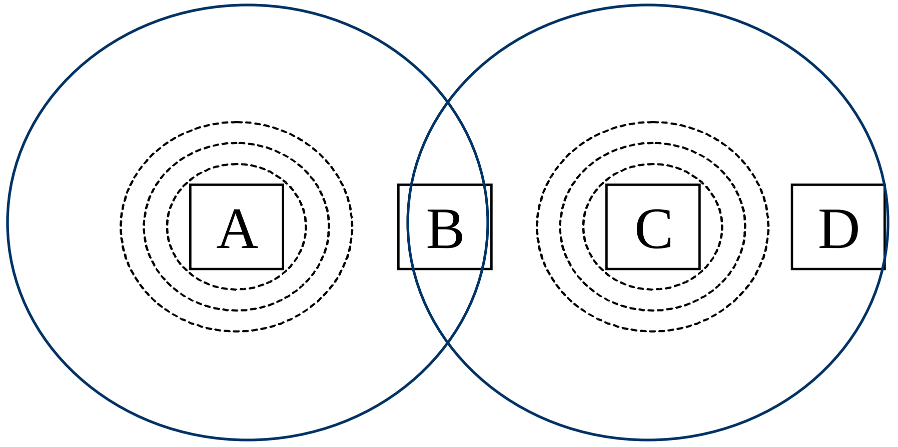
Carrier Sense Multiple Access Collission Detection (CSMA/CD)



Hidden station problem

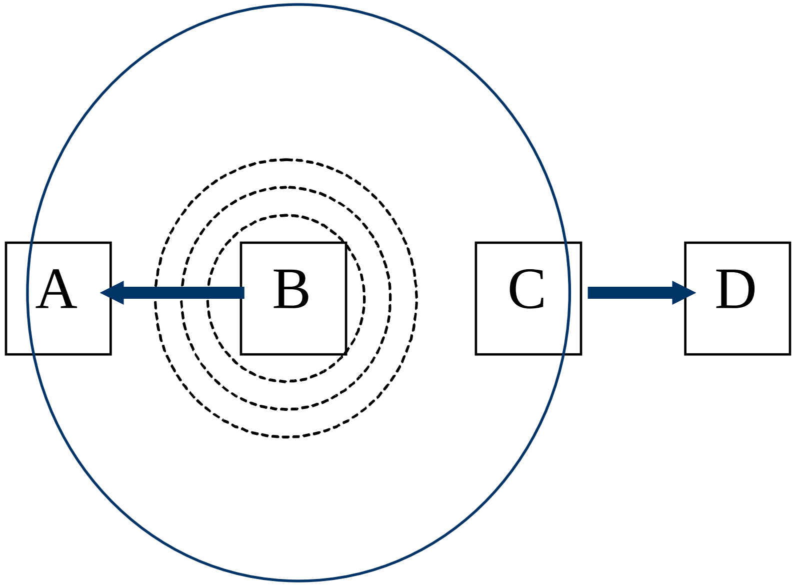
- A sends to B
- C does not listen to A
- C sends to B
- Collision at B
- A and C does not detect collision
- CSMA/CD not efficient in wireless





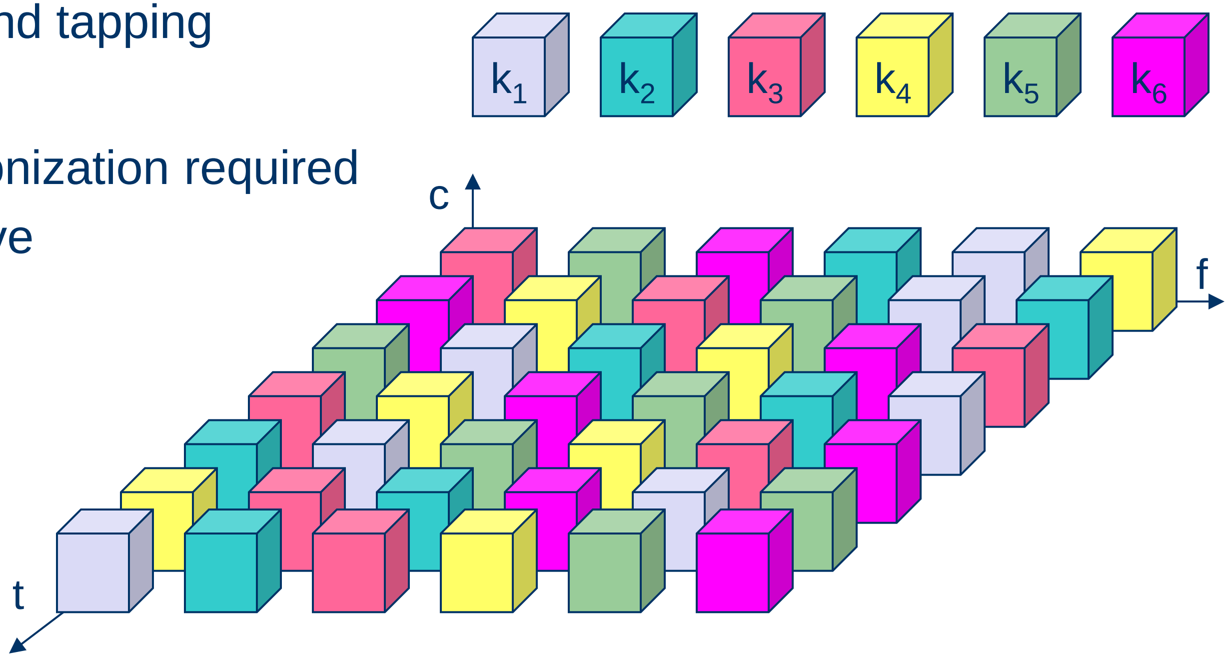
Visible station problem

- B sends to A
- C wants to send to D
- but
  - C listens to B
  - C does not transmit to D (while he could)



Hybrid TDM/FDM

- Combination of both methods
- A channel gets a certain frequency band for a certain amount of time (slot).
- Advantages:
  - better protection against interference and tapping
- Disadvantages:
  - Better synchronization required
  - More expensive

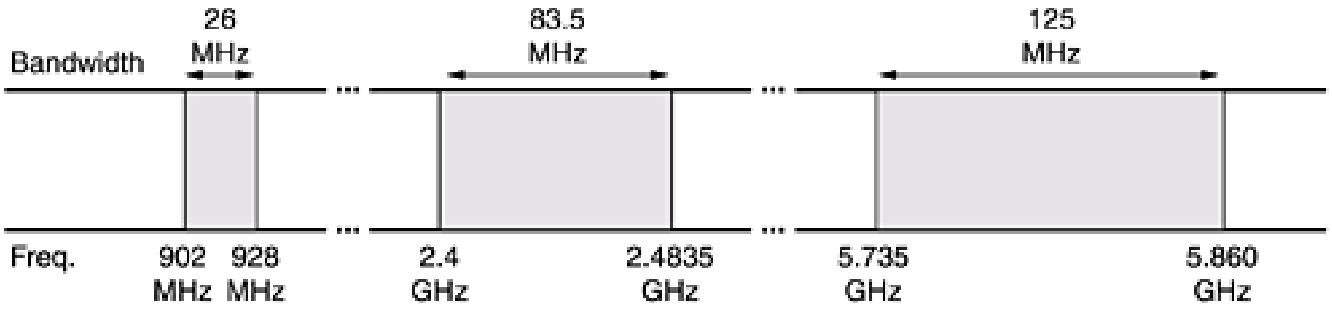


Δίκτυα τύπου IEEE 802.11

WiFi

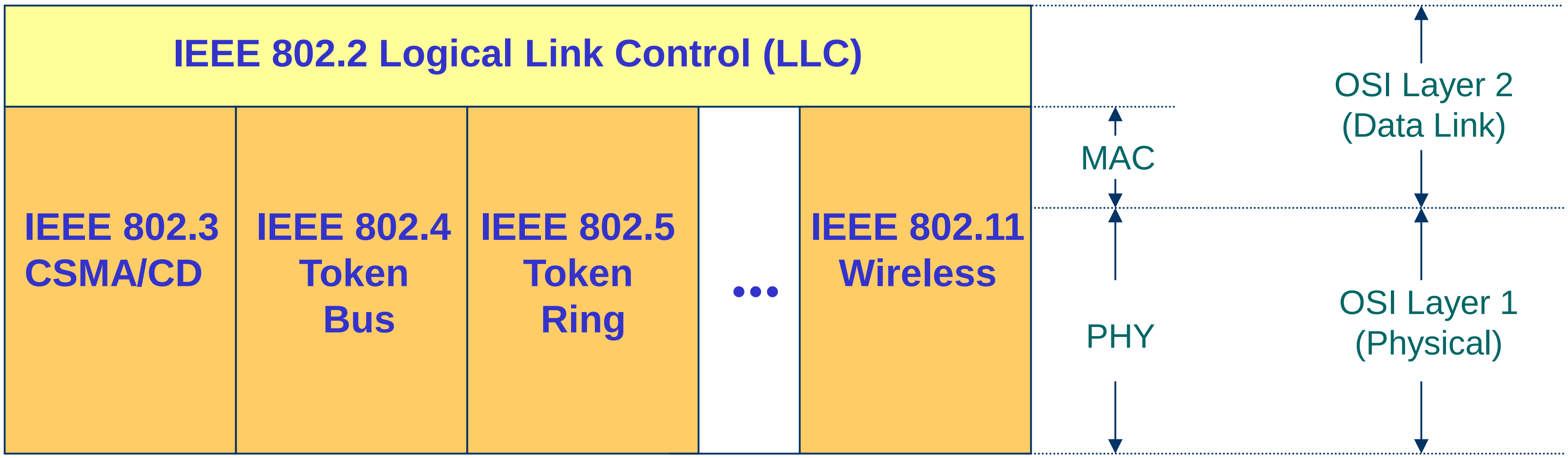
- At 1997 IEEE issued standard IEEE Std. 802.11-1997 for wireless local transmissions at the ISM band.
- The standard defines MAC and PHY layers for wireless local environments.
- Standard 802.11 provides 2Mbps at 2,4GHz ('97).
- Extension 802.11b provides 11Mbps at 2,4GHz ('99).
- Extension 802.11a provides 54Mbps at 5GHz ('99) through OFDM.
- Extension 802.11g offers 54Mbps at 2,4GHz ('02) through OFDM.
- Extension 802.11n offers up to 600Mbps at 2,4/5GHz through MIMO.

ISM Band (Industrial Scientific Medical)

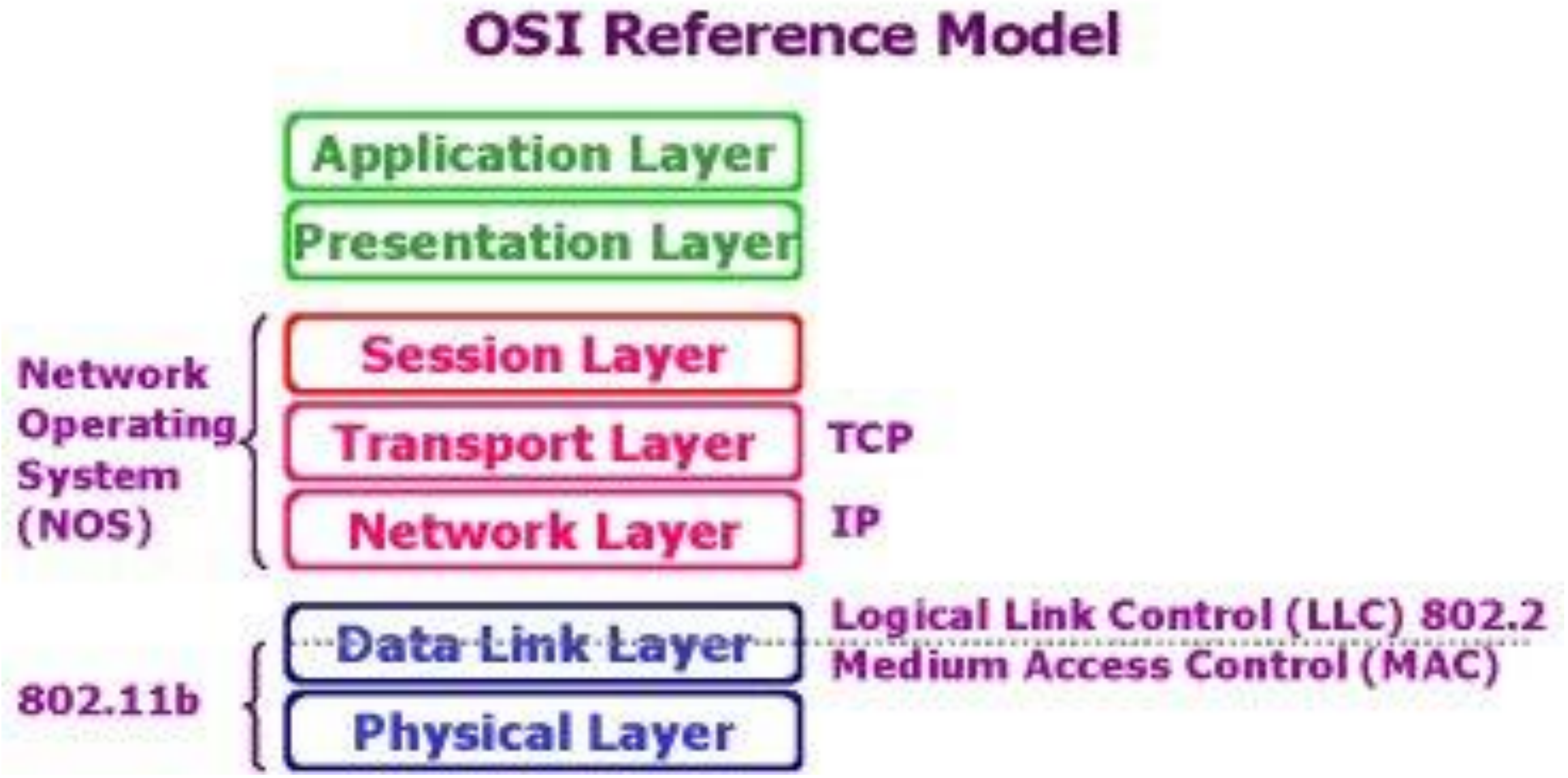


- Free to use without the need for a license
- Used mainly for WLANS

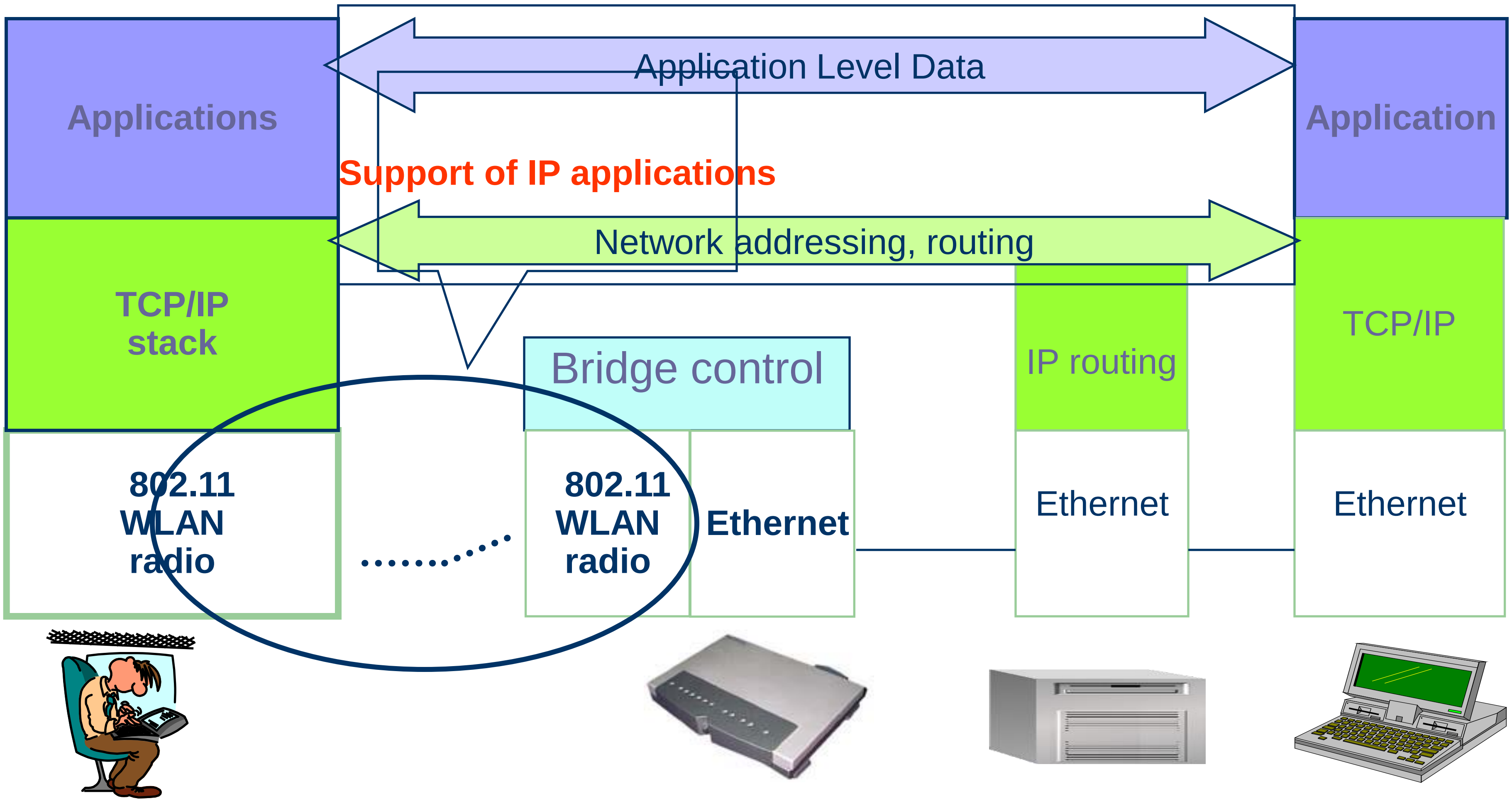
The 802.x family of standards



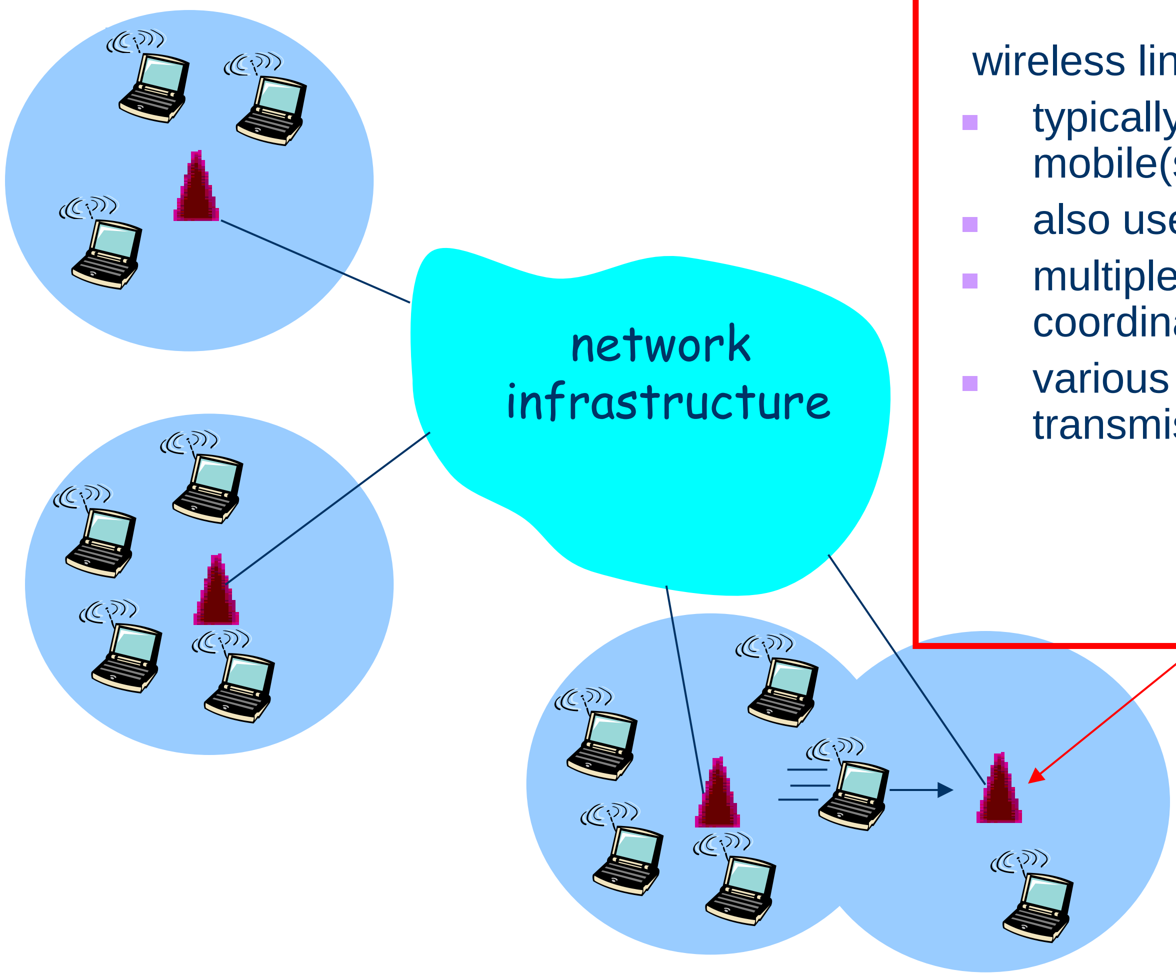
The 802.11 protocol stack



802.11 – Wireless Ethernet



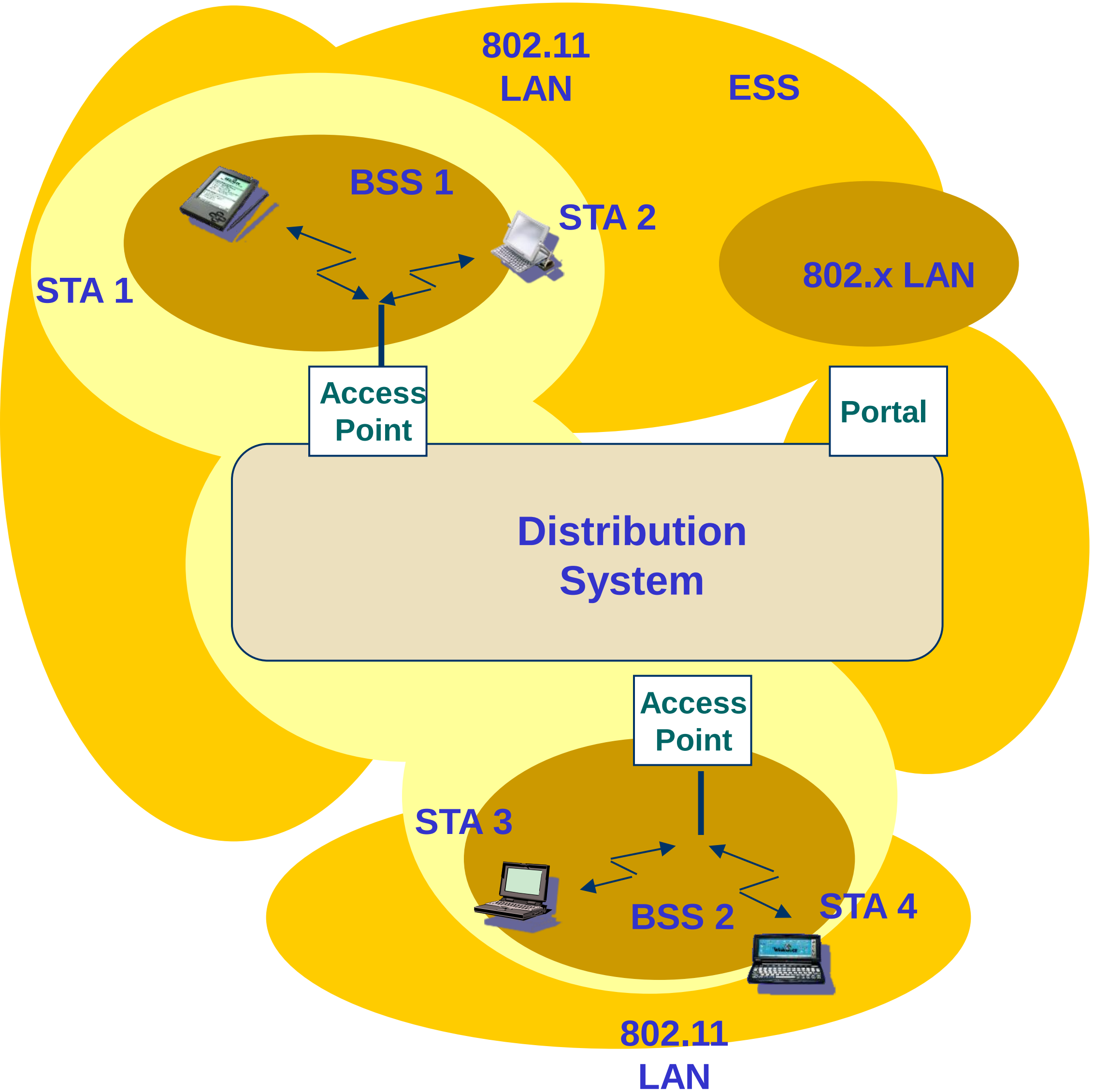
Elements of a wireless network



wireless link

- typically used to connect mobile(s) to base station
- also used as backbone link
- multiple access protocol coordinates link access
- various data rates, transmission distance

802.11 Infrastructure based



Station (STA)

Terminal with capabilities to communicate with the AP Access Point

Basic Service Set (BSS)

Group of stations using the same radio frequency

Access Point

A station that communicates both with the wireless LAN and the distribution system

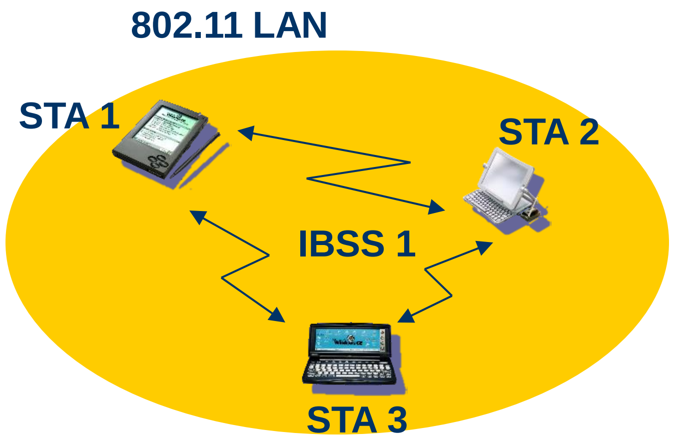
Portal

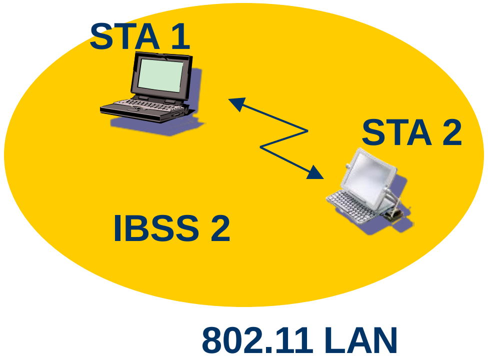
Bridge between the distribution system and external networks

Distribution System

Network connection multiple BSSs in one ESS (Extended Service Set)

802.11 Ad-Hoc





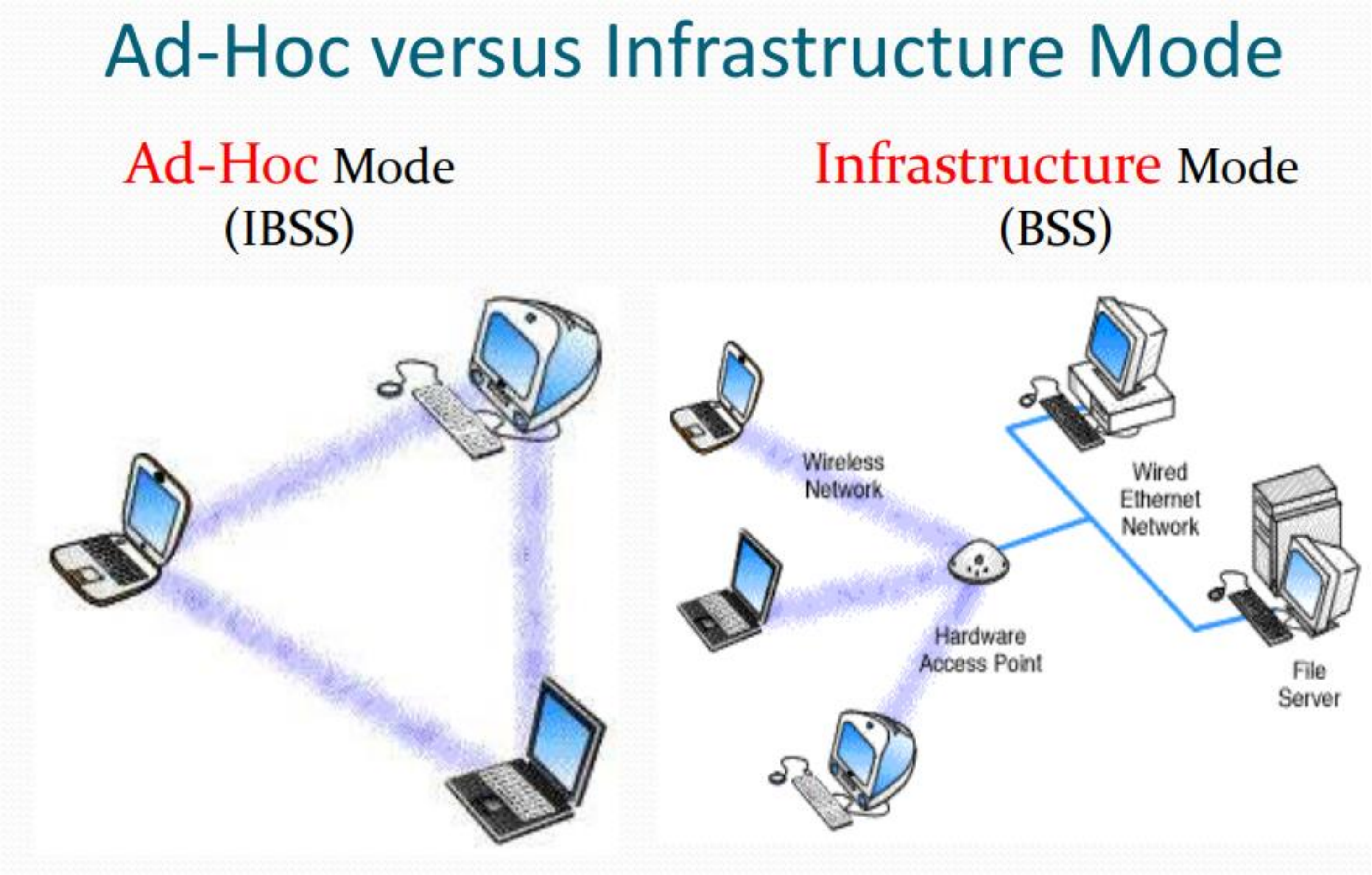
Station (STA)

Terminal with capabilities to communicate with the AP Access Point

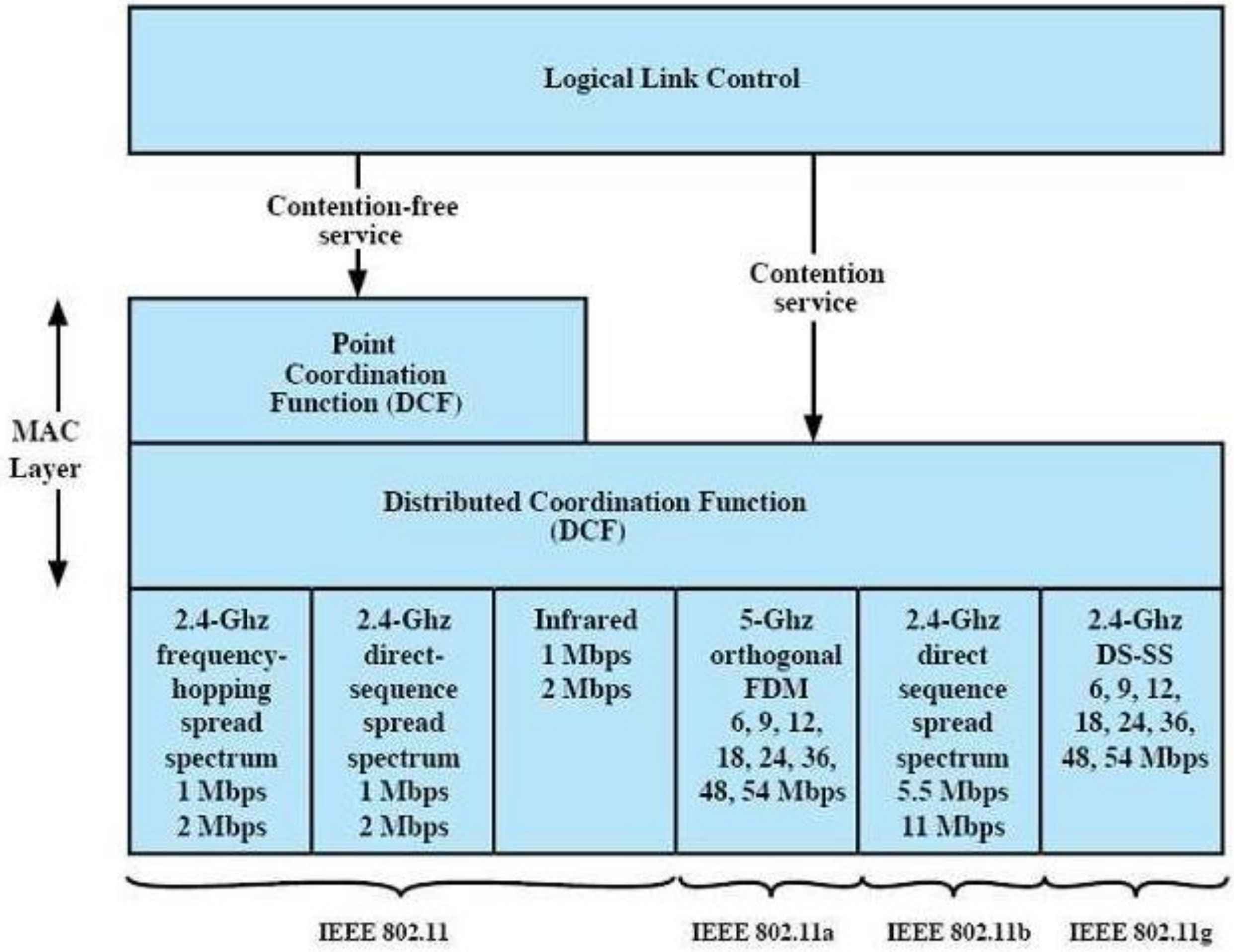
Independent Basic Service Set (IBSS)

Group of stations communicating at the same frequency without the need for an AP

Two modes of operation

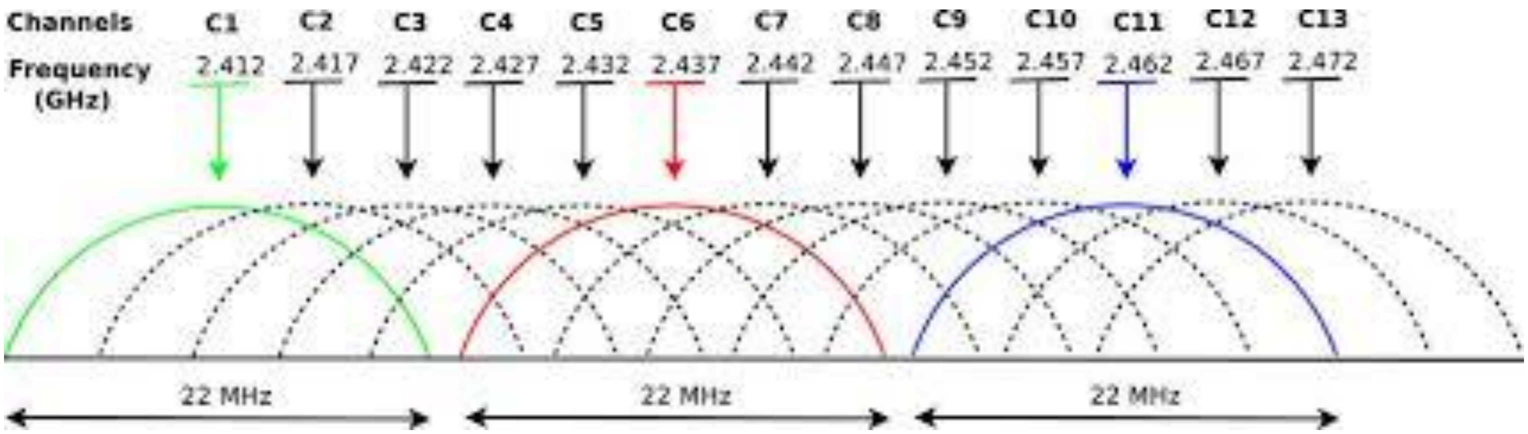


Protocol stack of 802.11

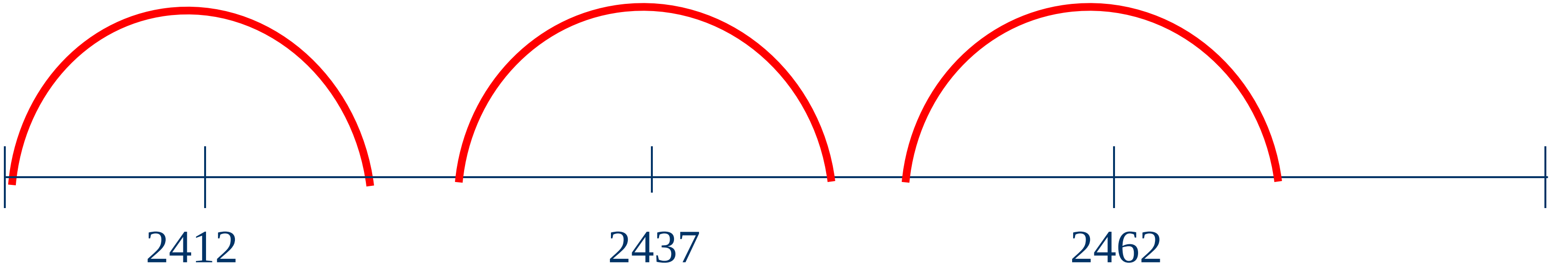


802.11b transmission channels

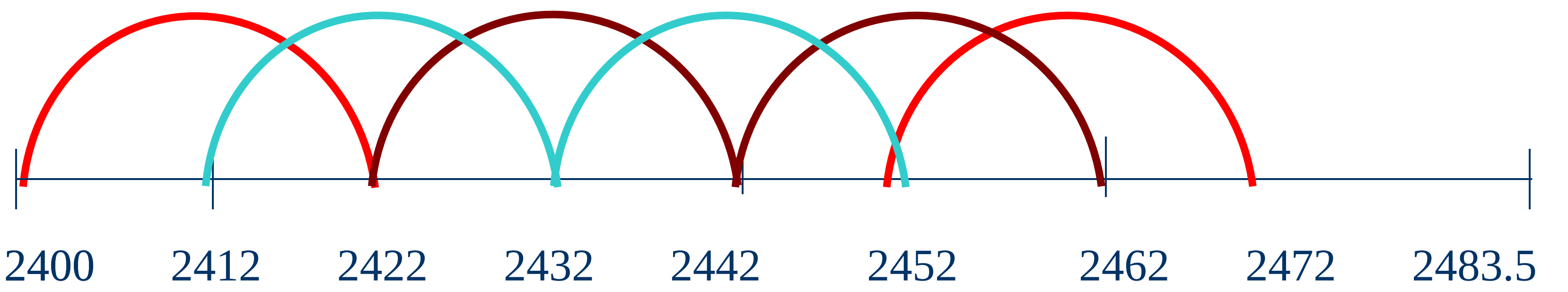
- PHY of 802.11b manages 14 channels, 22MHz wide each placed 5MHz from each other
- Channel is placed around 2.412 GHz, channel 2 around 2.417 GHz, etc, until channel 14 at 2.477 GHz
- 3 non overlapping



Non overlapping channels

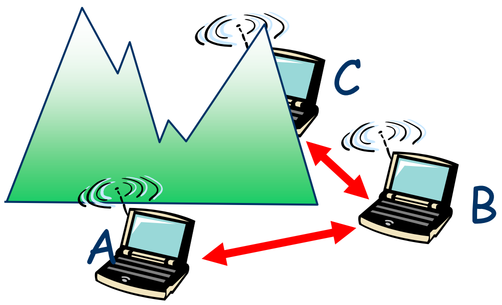


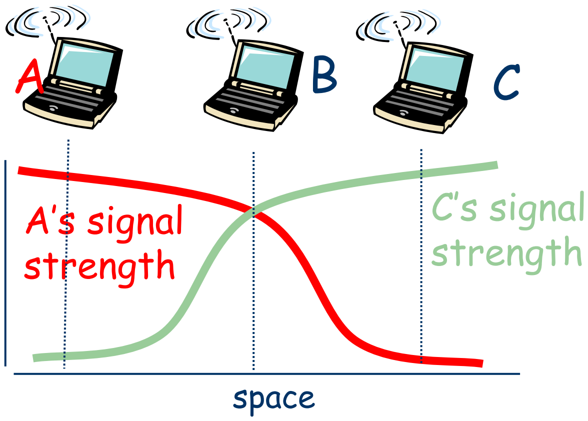
Overlapping channels



How to avoid collisions

- Collisions: 2^{+} nodes transmitting at same time towards a receiver
- Carrier sensing - sense before transmitting (CSMA)
  - The transmitter may not listen an ongoing transmission
- Collision detection – detect if a collision accured (CSMA/CD)
  - Can't sense all collisions in any case: hidden terminal, fading
- Goal: *Avoid collisions:* CSMA/C(ollision)A(voidance)

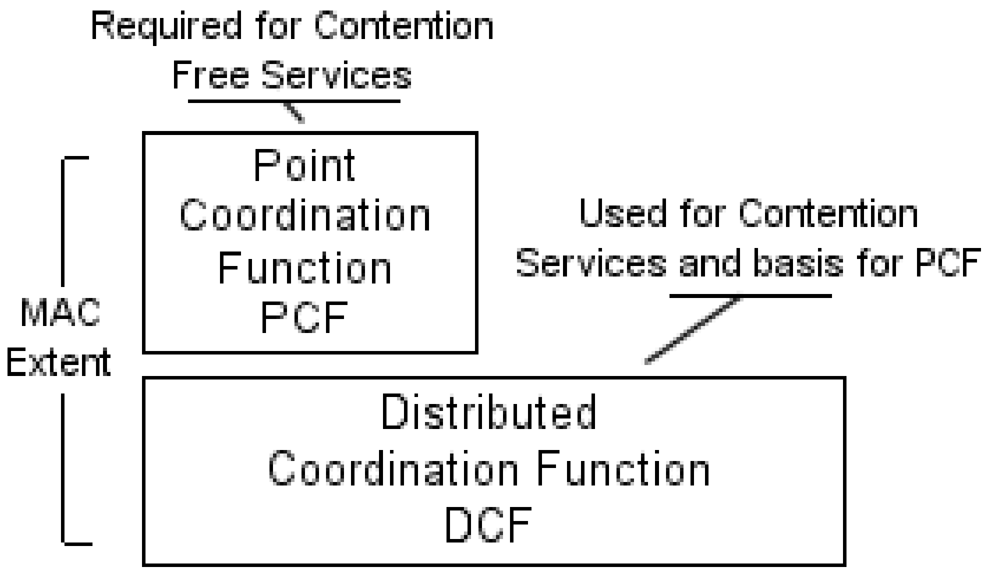


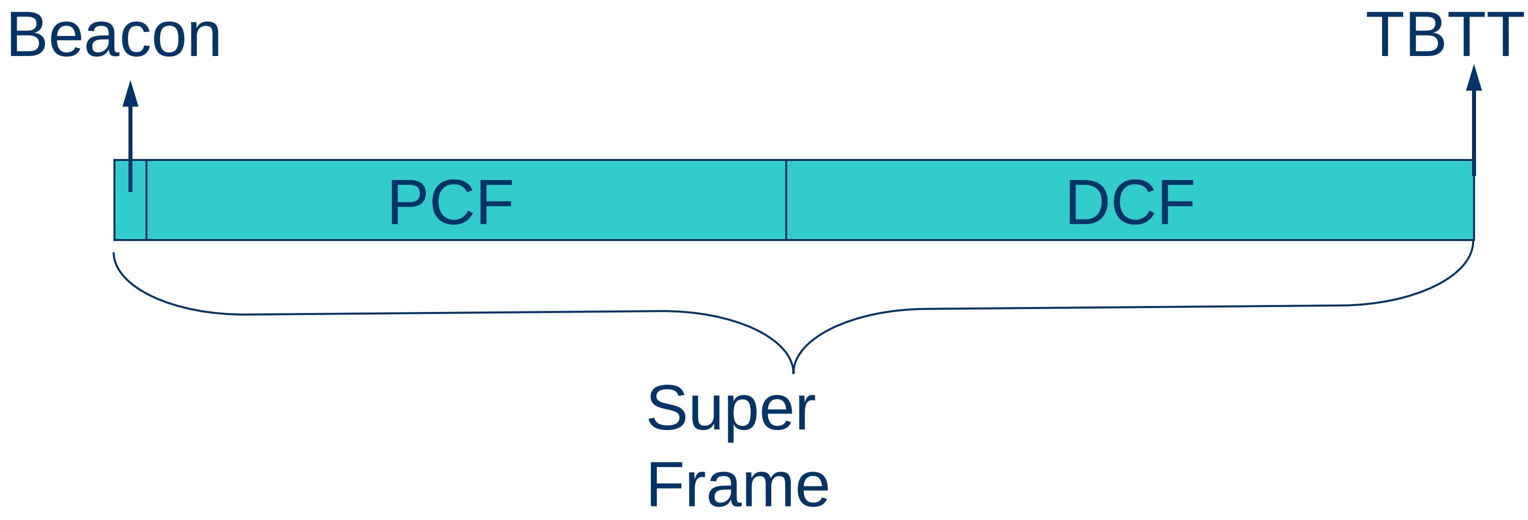


Access Methods

Distributed Coordination Function (DCF)
- Mandatory
- Main access mode
- Contention-based

Point Coordination Function (PCF)
- Optional
- Contention-free
- Lower delays in high traffic
- Only in infrastructure mode





DCF - Distributed Coordinated Function

(**Contention Period** - *Ad-hoc Mode*)

PCF - Point Coordinated Function

(**Contention Free Period** – *Infrastructure BSS*)

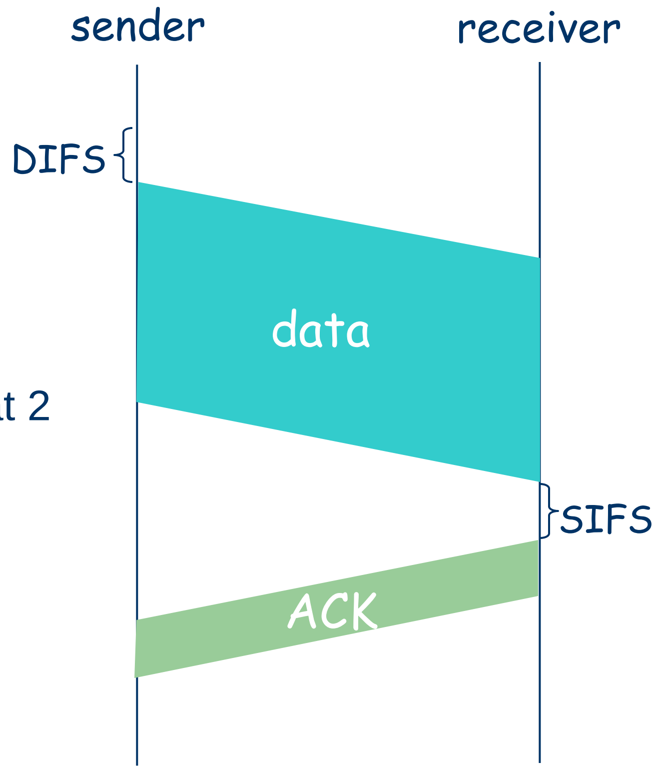
Beacon - Management Frame

Synchronization of Local timers

Delivers protocol related parameters (e.g., version)

TBTT (Target Beacon Transition Time)

IEEE 802.11 MAC Protocol: CSMA/CA



802.11 sender

1 if sense channel idle for **DIFS** then

transmit entire frame (no CD)

2 if sense channel busy then

start random backoff time

timer counts down while channel idle

transmit when timer expires

if no ACK, increase random backoff interval, repeat 2

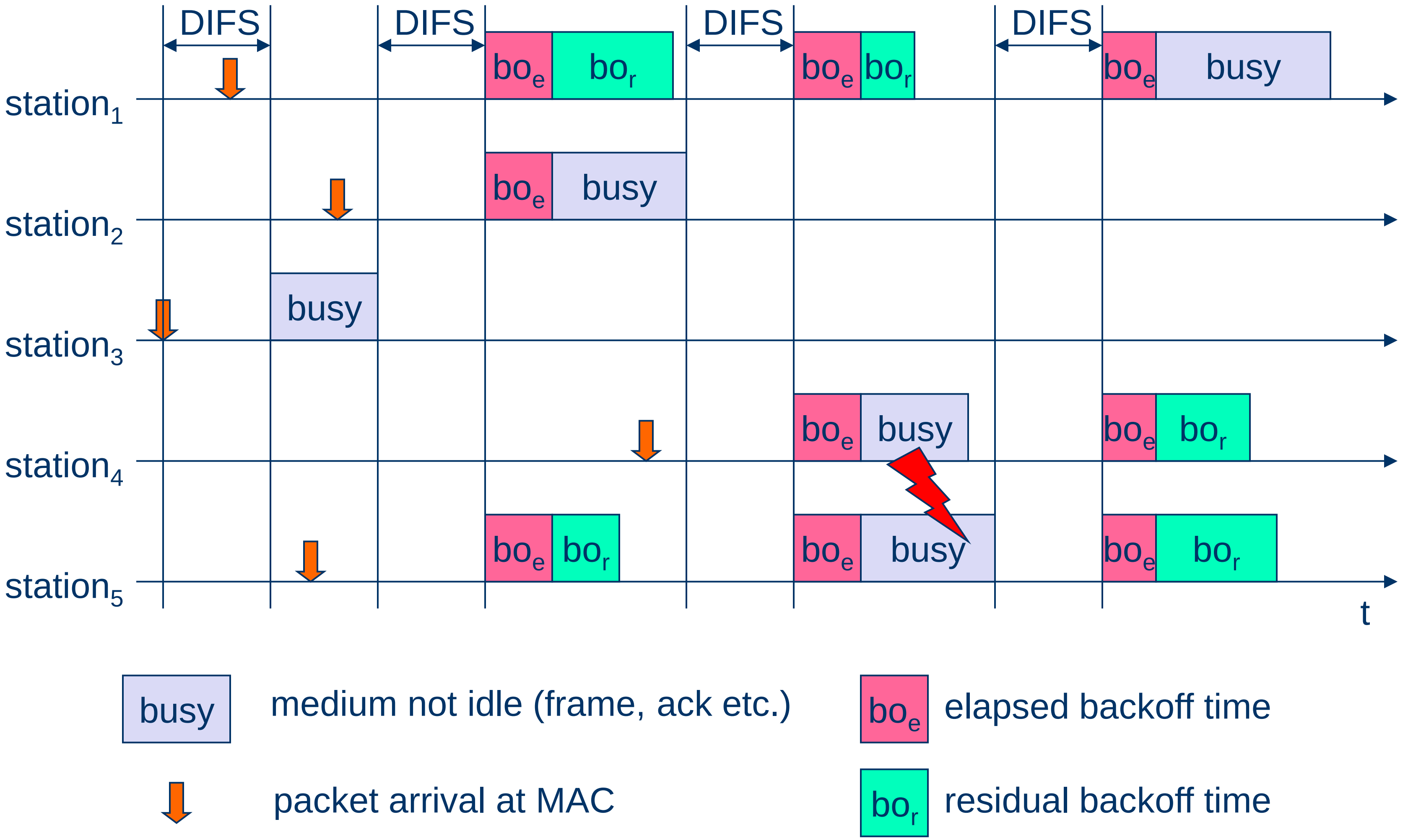
802.11 receiver

- if frame received OK

return ACK after **SIFS** (ACK needed due to hidden terminal problem)

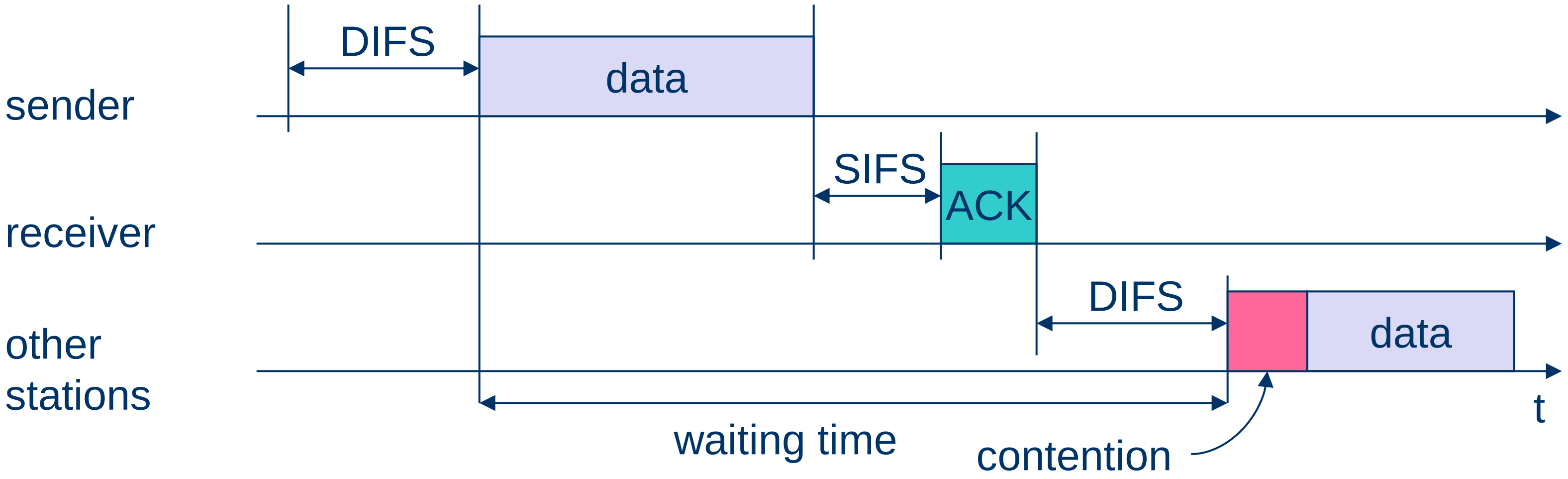
SIFS<DIFS

802.11 - competing stations - simple version



802.11 - CSMA/CA access method

- Sending unicast packets
  - station has to wait for DIFS before sending data
  - receivers acknowledge at once (after waiting for SIFS) if the packet was received correctly (CRC)
  - automatic retransmission of data packets in case of transmission errors



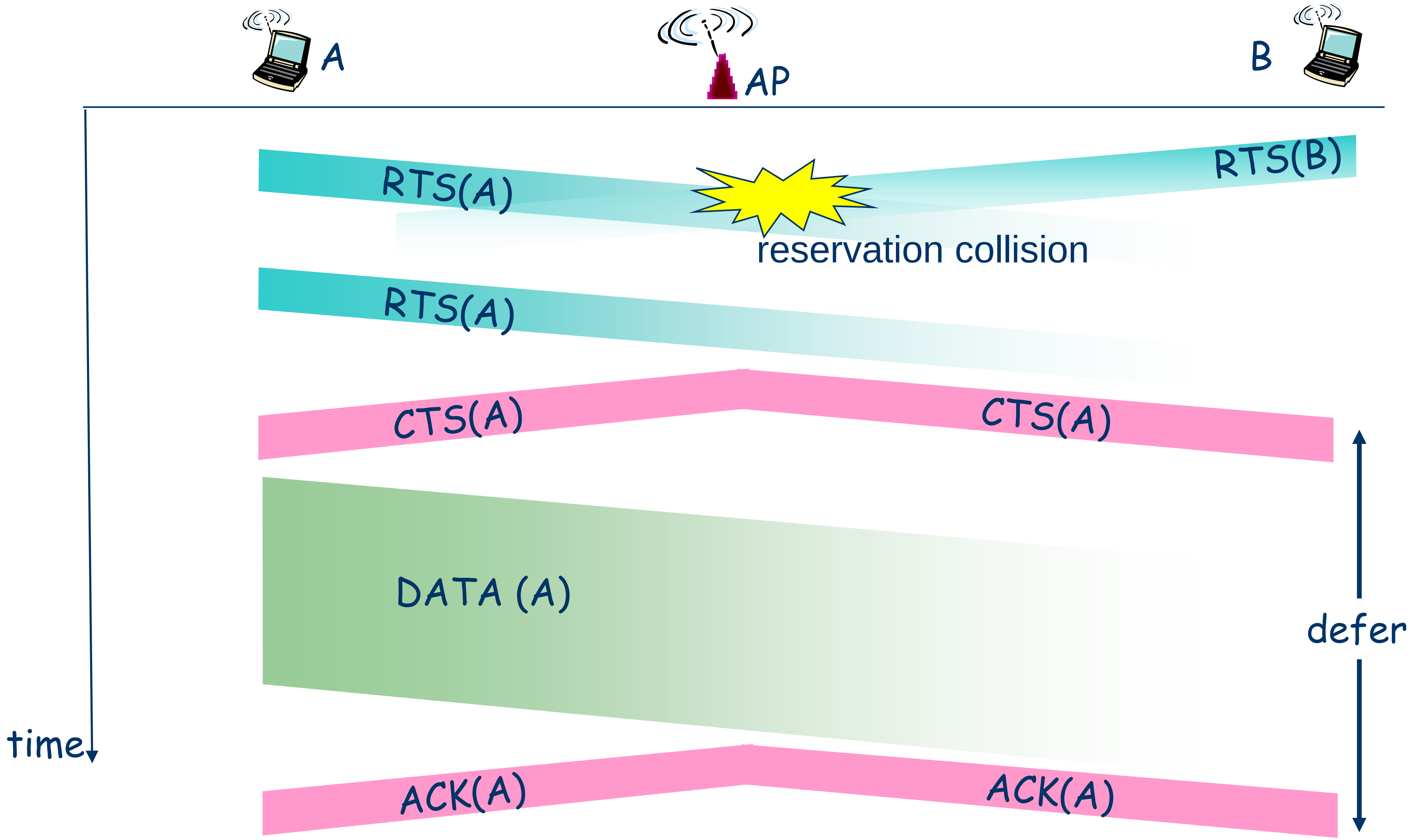
Avoiding collisions (more)

idea: allow sender to "reserve" channel rather than random access of data frames: avoid collisions of long data frames

- sender first transmits *small* request-to-send (RTS) packets to BS using CSMA
  - RTSs may still collide with each other (but they're short)
- BS broadcasts clear-to-send CTS in response to RTS
- CTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

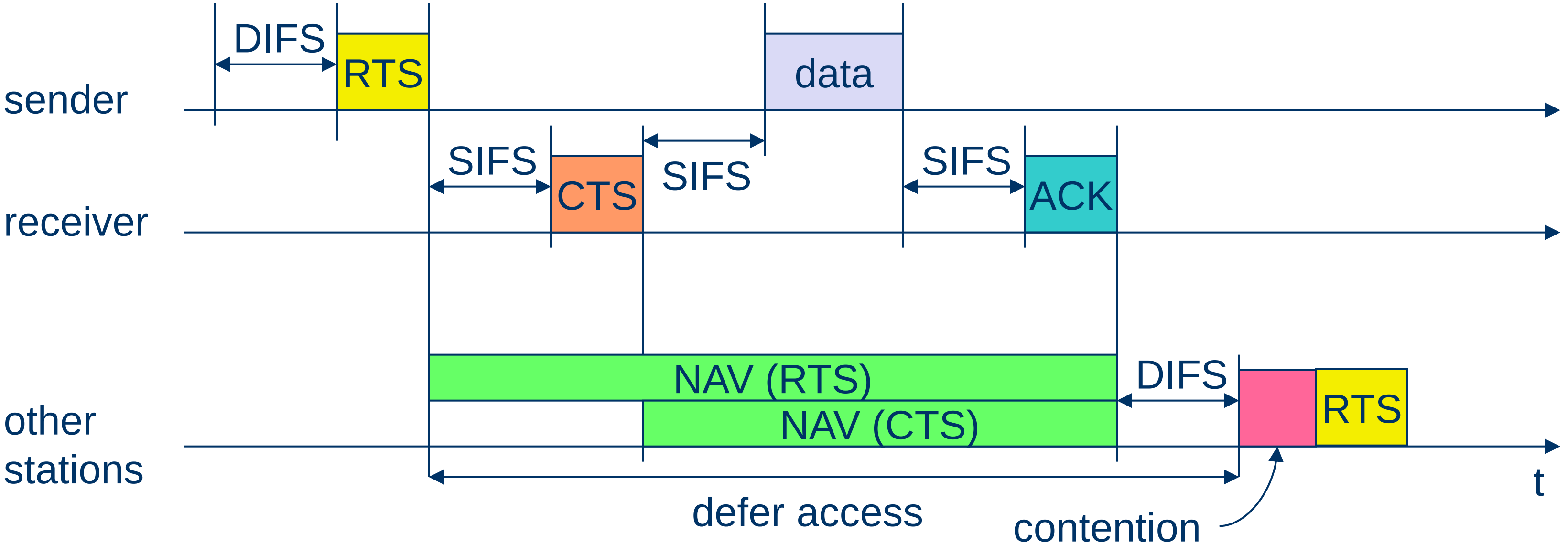
avoid data frame collisions completely
using small reservation packets!

Collision Avoidance: RTS-CTS exchange

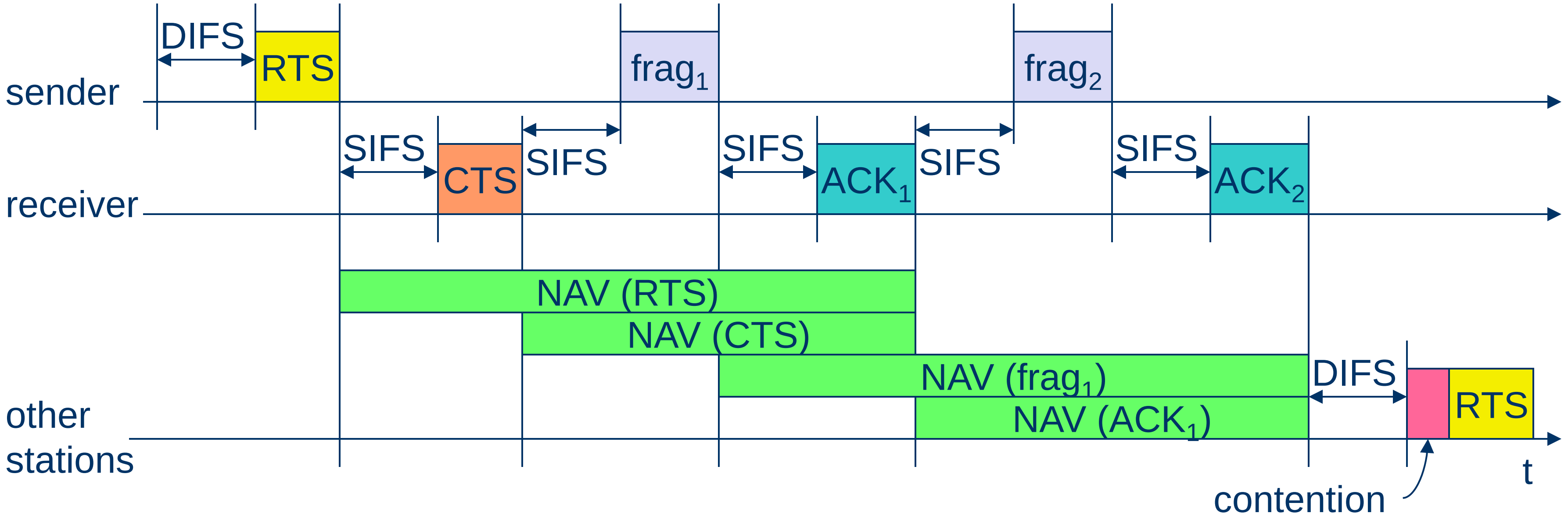


Collision Avoidance: RTS-CTS exchange

- Sending unicast packets
  - station can send RTS with reservation parameter after waiting for DIFS (reservation determines amount of time the data packet needs the medium)
  - acknowledgement via CTS after SIFS by receiver (if ready to receive)
  - sender can now send data at once, acknowledgement via ACK
  - other stations store medium reservations distributed via RTS **and** CTS

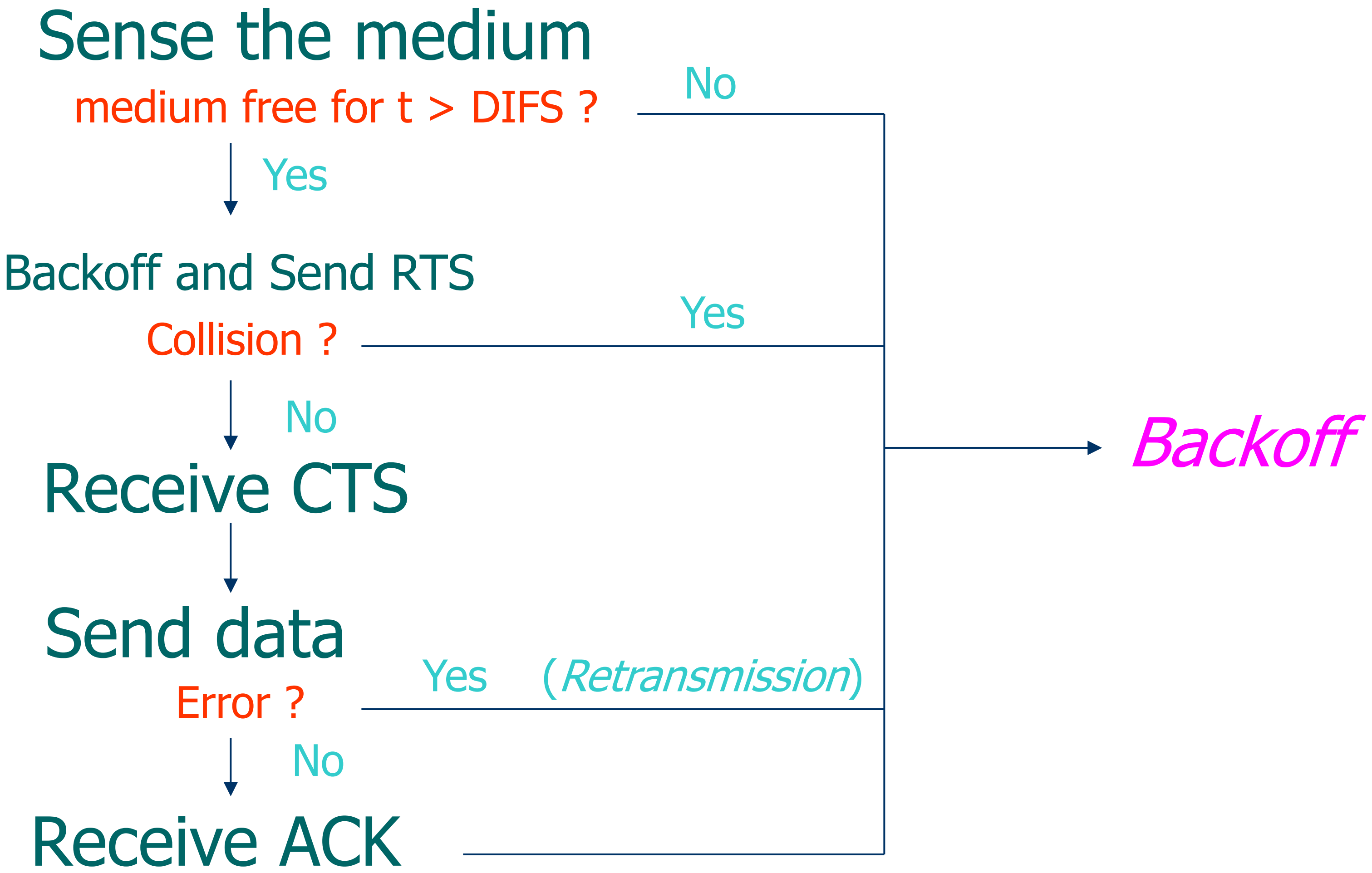


Fragmentation



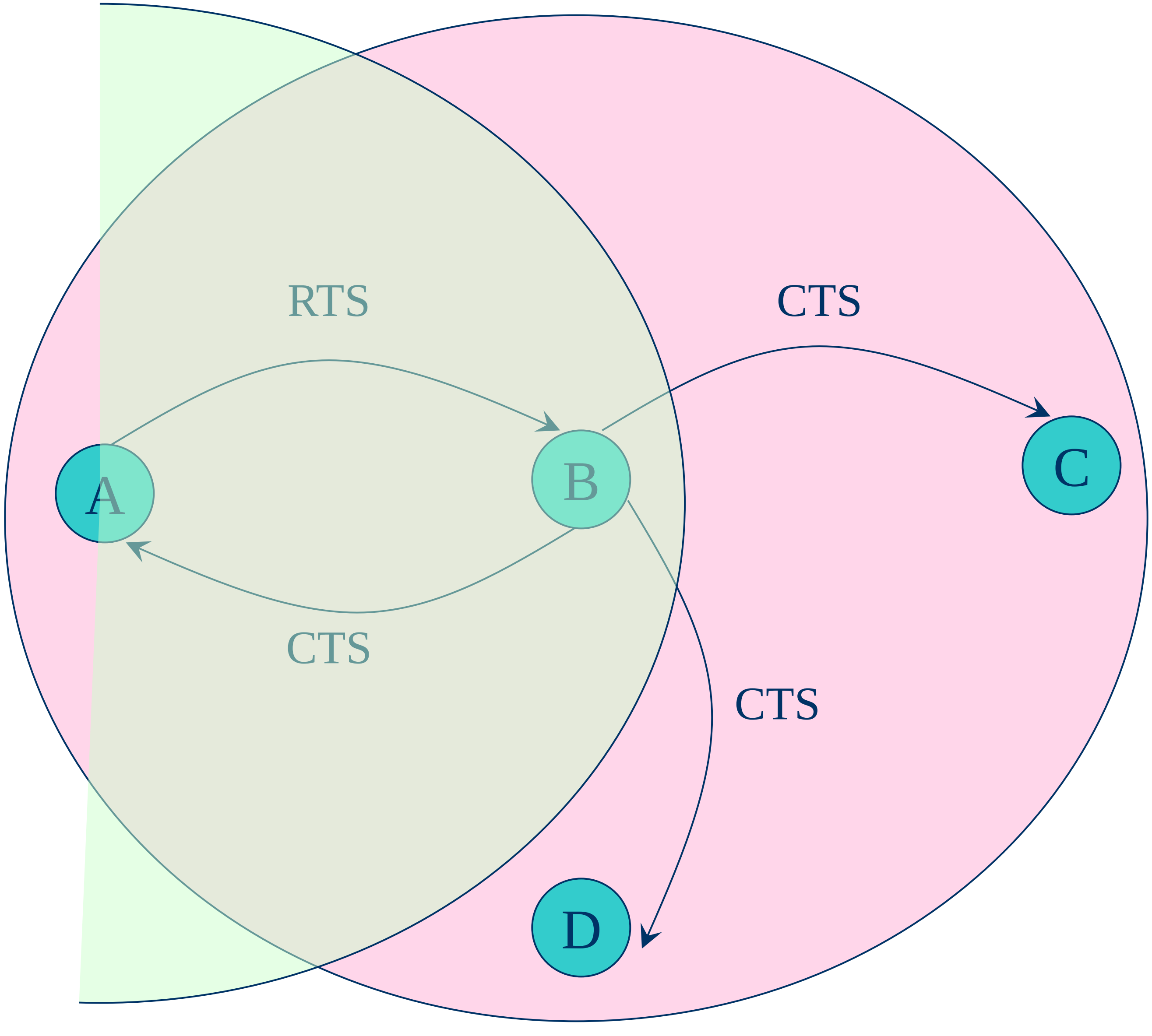
Why fragment?

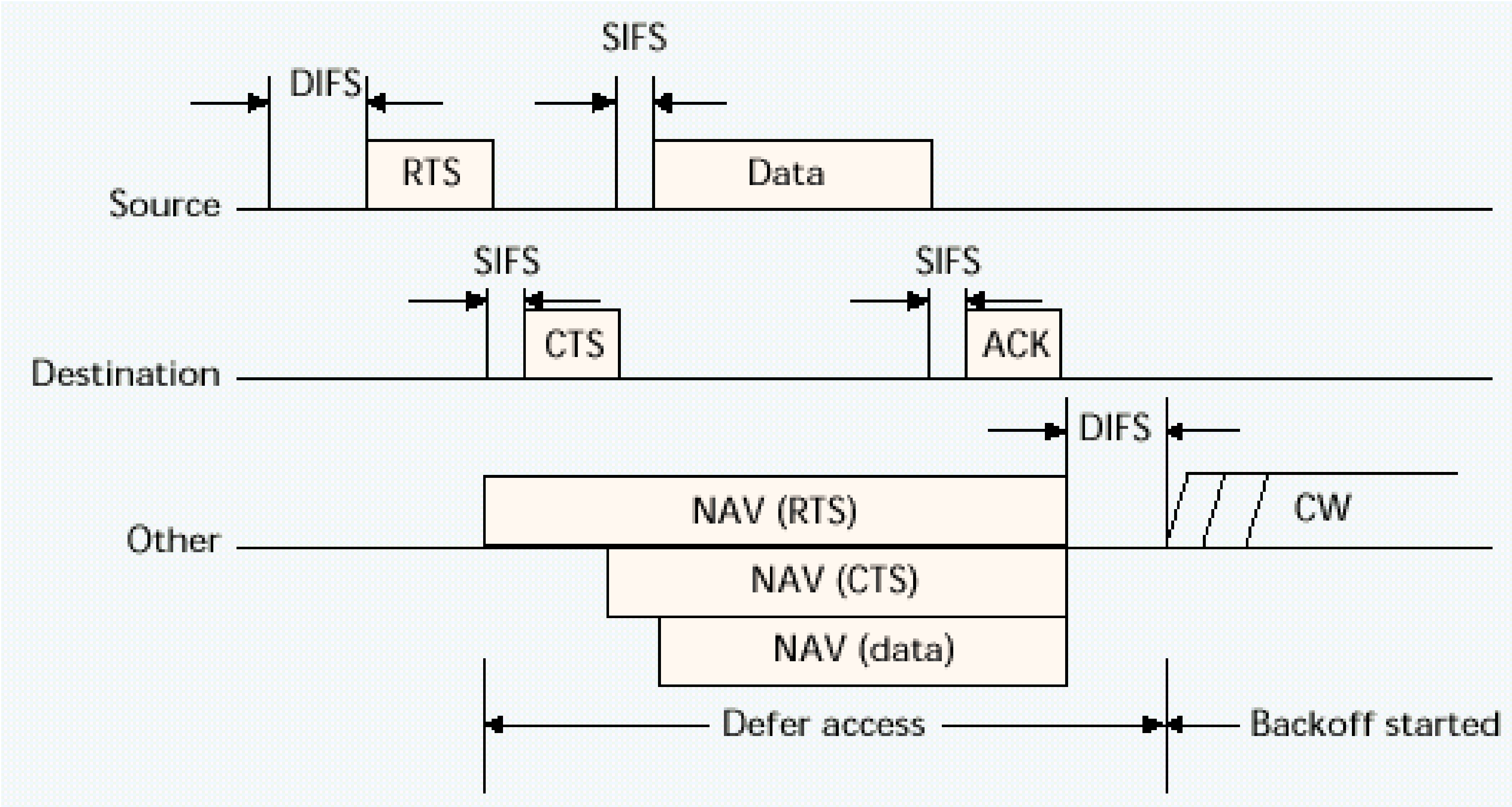
Distributed Coordination Function



DIFS: DCF Interframe Space

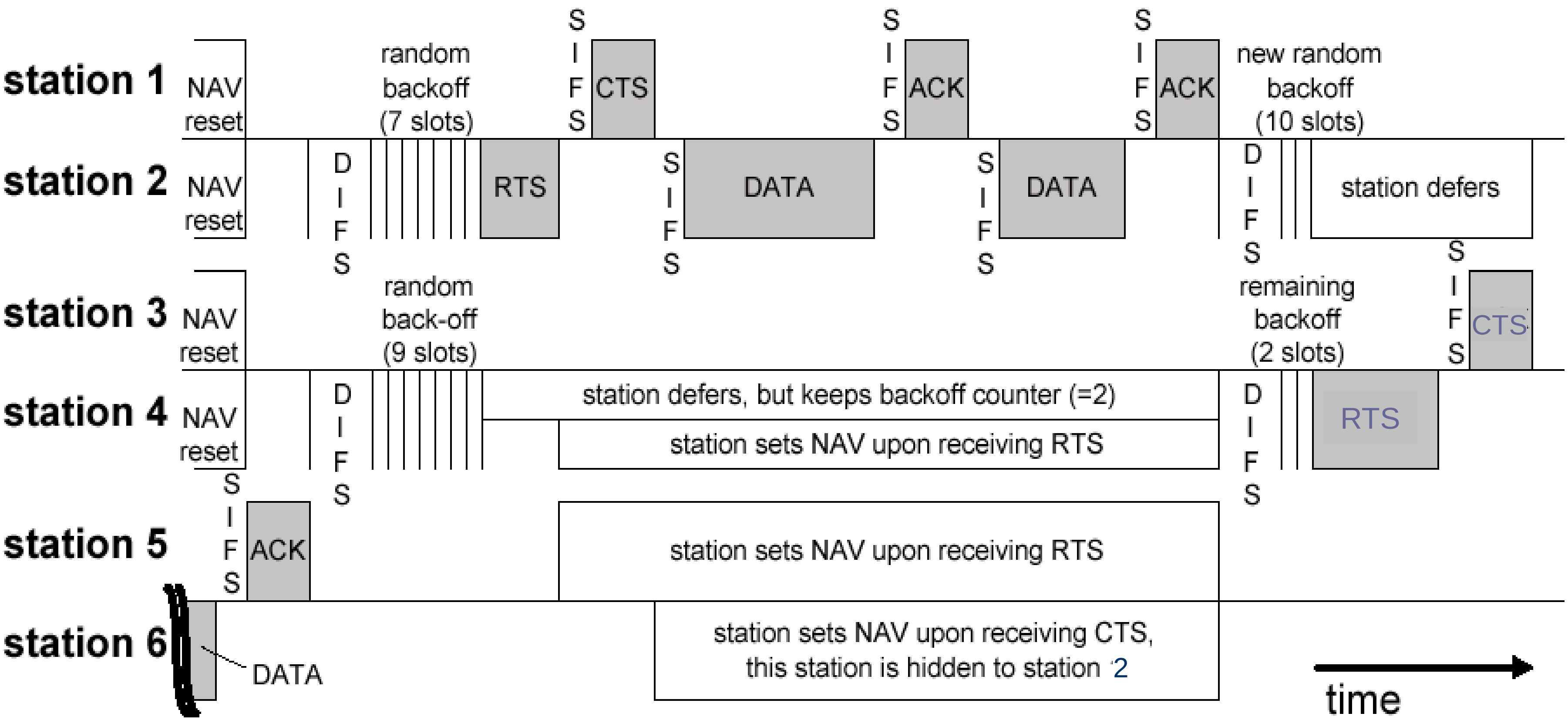
Collision avoidance at station B





- Always SIFS<DIFS
- Updating of NAVs (Network Allocation Vectors) very important through RTS/CTS/data packets to use power saving

Example of DCF transmission



CW doubles after each collision

- Initial CW -> 3 (backoff 0-3)
- CW after Collision 1 → 7 (backoff 0-7)
- CW after Collision 2 → 15 (backoff 0-15)
- CW after Collision 3 → 31 (backoff 0-31)
- CW after Collision 4 → 63 (backoff 0-63)